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THE CANADIAN GEOGRAPHER

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LE GÉOGRAPHE CANADIEN

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PROBLEMS OF URBAN GROWTH IN GREATER MONTREAL

CLAUDE LANGLOIS

Central Mortgage & Housing Corporation

MONTREAL, in many ways, is different from most other large North-American cities. However, during the last fifteen years it has experienced the same suburban boom, and has spread into the rural areas in the same spoiling and monotonous fashion. Montreal has even shown tendencies to become as dull as Toronto where, as Scott Symons says, dullness is established as a system.[1] The recent growth of Montreal has been influenced by the same forces, but its suburban sprawl has retained a local flavour both in its pattern and in its tempo.

The factors which have influenced the urban growth of Montreal during the last fifty years as well as during the last fifteen are numerous. However, four which have played perhaps the predominant role in shaping present-day Montreal are: first, the unusual site on which Montreal is built; secondly, its two predominant cultures, or as Canada's Prime Minister would say, her bilingual culture; thirdly, the changing functions of the Canadian metropolis; and finally, the land speculation which has established the detailed pattern of urban growth.

MONTREAL: THE SITE

Montreal is built on an archipelago, formed of two main islands, two medium-sized islands, and scores of islets. These various islands are separated by important arms of polluted water, creating tremendous transportation difficulties. Montreal is also ornamented by a so-called mountain, Mount-Royal, protruding through the centre of the island. This, outside of being a beautiful park, accounts for a large part of the traffic circulation problem Montrealers have to face, and in addition has brought quite normally a vertical social class stratification in the population. There are also two other physiographic features which, although they have a lesser influence today, are worth mentioning. One is a steep bluff running for some ten miles parallel to the St. Lawrence River, from one to one-and-a-half miles inland, and which for a long time blocked development and spread urban growth to the east and west.[2] The other is comprised of two smaller terraces located between the bluff and the river, which in the past have affected the urban growth less directly.

The greatest consequence of these physical characteristics is that urban growth has concentrated around the bridge-heads and along the roads leading to these bridges. The mountain blocked northward expansion and had to be circled. The bluff had to be surmounted. Both of these features were overcome only with great difficulties and expense.

MONTREAL: THE TWO CULTURES

There are two predominant cultures in Montreal, one French-speaking, and the other English-speaking. While the French Canadians account for sixty-five to seventy per cent of the total population of some two million people, the Montrealers of Anglo-Saxon origin account for about twenty to twenty-five per cent. The English-speaking Montrealers, despite their numerical inferiority, retain nevertheless, as a remnant of past history, the dominant positions in trade and industry, and attract to themselves a substantial part of the non-French and non-British immigrants. The French Canadians, who supply a very large part of the labour force in the industrial sector of the economy, are, however, gradually occupying key administrative posts at the regional level, especially as the activities of Montreal become more directly linked to the economy of the province.

The presence in Montreal of these two major ethnic groups has given the city a

decisive characteristic. For all practical purposes, Greater Montreal has two well-defined zones: one is French, concentrated in the east, on Ile Jésus to the north, and on the south shore of the St. Lawrence River; the other is English, which is mainly in the west with some secondary ramifications north and south. These two zones not only correspond to different ethnic groups, but they also correspond to different attitudes and behaviour from their population. The dividing line between East and West Montreal corresponds approximately to St. Lawrence Boulevard, and is rarely crossed by a family in its migrations throughout the city, except for work purposes.

This division of the city, and all the values attached to the two predominant cultures have in turn greatly affected not only the pattern of growth, but also its mode and its type.

MONTREAL: THE CHANGING FUNCTIONS

Since the beginning of the century, the growth of Montreal has proceeded by successive waves as the functions of the city changed. In 1910, Montreal stood as the capital of a financial and commercial empire. Its tightly clustered 125,000 dwellings occupied only a relatively small part of the island, between the St. Lawrence River and the bluff. A great portion of the housing stock of that period has now been demolished or altered to make room for the ever-growing commercial and financial district. The social characteristics of the city at the beginning of the century corresponded to the functions it fulfilled. The social structure in the Montreal of 1910 was composed of a numerically important upper class, a preponderant "bourgeoisie" class engaged in commercial and financial enterprises—the then predominant function of Montreal—and a numerically unimportant lower class, working in the few existing industries.

During the First World War, Canada's centre of population shifted westward, and Quebec entered a new phase of industrialization. The consequent urbanization gave Montreal a completely new personality. Losing its predominance as a commercial and financial metropolis, it evolved as a major manufacturing centre. Its strategic location on the St. Lawrence River, at the convergence of main transportation routes and in the heart of the agriculturally rich Montreal Lowlands, greatly fostered its development as supplier of manufactured products to Canada. These changing functions accelerated the growth of the city, as well as the nature of its population and its pattern of growth. The development of the manufacturing industry attracted a large number of in-migrants from surrounding rural areas and immigrants from abroad.

The social structure changed rapidly as the lower-class working population grew in importance and soon became predominant. This large influx of people had to be housed quickly; more than 150,000 dwellings had to be supplied to the new city-dwellers between 1901 and 1931. The lack of initial capital and the low income of the newcomers prevented them from becoming home-owners. At the same time, those who had funds, being motivated by the values of sound investment which was an outgrowth of their rural background, and seeing the profit opportunity, invested in multi-unit buildings. Houses erected during that period were generally of the row type, three storeys high, with exterior stairs. Because of this particular situation, Montreal now holds a unique characteristic for North American cities; it is built predominantly with rental units. In fact, seventy per cent of the 500,000 dwellings in Greater Montreal are occupied by tenants. Furthermore, of these 350,000 rental dwelling units, over 200,000 are in buildings containing fewer than six units, while only 135,000 are apartment units proper.

It is often believed this large proportion of rental units is linked with the French-Canadian culture. Such a relation cannot be positively established, as Lacoste has shown in his book on the social characteristics of the population of Greater Montreal.[3] He has established that English-speaking Montrealers are tenants in as high a proportion as French-speaking Montrealers. This phenomenon is believed to be, on the one hand, an economic remnant of the 1910–1930 era, and, on the other hand, linked directly with the social atti-

tudes and behaviour of a working-class population, since even today some seventy-five per cent of the new units built yearly in the Greater Montreal area are of the rental type. The only direct relation which can be positively established is between the type of rental unit and the ethnic origin. In the districts inhabited by French Canadians, more than seventy-five per cent of the rental units are of the duplex, triplex, or multiplex types, while in the districts inhabited by English-speaking Montrealers, seventy-five per cent of the rental dwellings are apartment units.

As with everywhere else in the world, the great depression of the thirties affected the economic development of Montreal. The population increased by only slightly more than 100,000 during this decade, and construction activities were considerably reduced. The exodus of relatively new immigrants and others transformed the acute housing shortage of the beginning of the decade into a surplus. Thus it was not before the Second World War that many of these dwellings were reoccupied by a rural population attracted to Montreal by the high salaries offered in the war industries.

After the war, the Quebec internal migration towards a metropolis in full prosperity and expansion was joined by a flow of immigrants from European countries, similar to that of the 1918–1930 period. This intense wave of migration into the city sparked the suburban expansion which Montreal has been undergoing so intensively over the past fifteen years. Industrial decentralization created new poles of activity as new transportation lines further accelerated this movement. This recent suburban sprawl has taken place in four different phases: (1) from 1945 to 1950, (2) from 1951 to 1955, (3) from 1956 to 1958, and (4) a last phase which began in 1959.

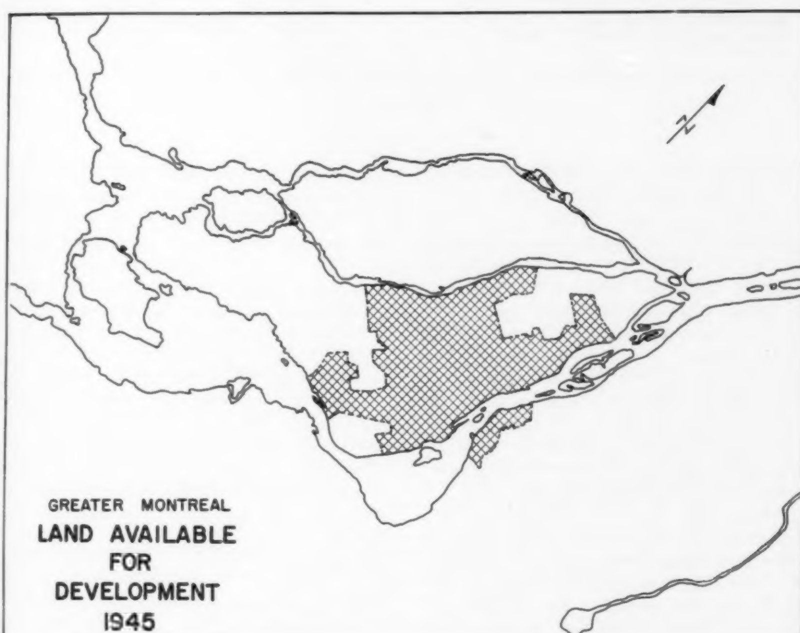

FIGURE 1

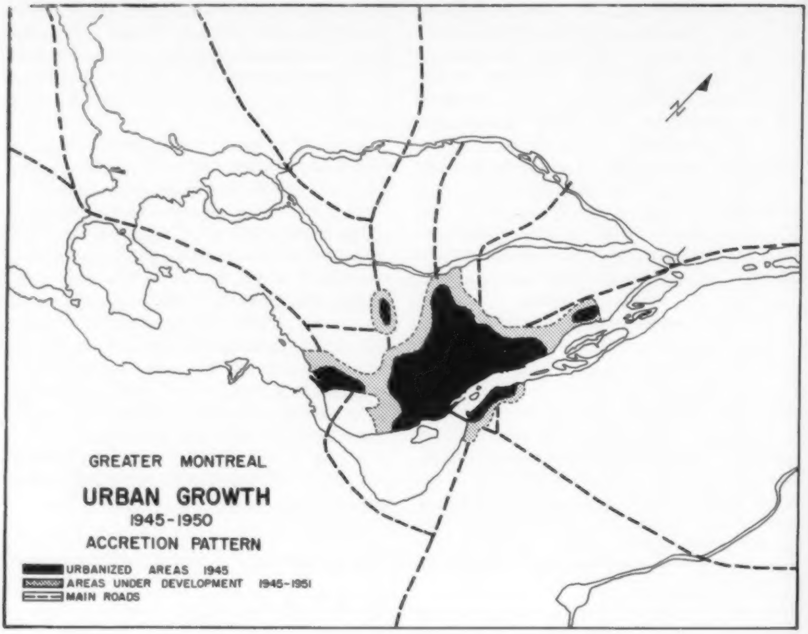

FIGURE 2

1945–1950 PHASE OF SUBURBAN GROWTH: THE ACCRETION PATTERN

Until 1945, the urban growth of Montreal had been rather concentrated in the city itself and in a small number of suburbs. Thus, in 1945, Montreal stood as a large mass of rental dwellings. At that time, Greater Montreal, as shown on the map (Figure 1) of land available for development in 1945 (which in fact should read more properly "Land Stated by Municipalities as Being Available for Immediate Urban Development"), was growing within an area of some 65,000 acres, comprised of 13 municipalities.

From 1945 to 1950, because of rapid industrial growth and the large influx of new population, a housing crisis developed in which thousands of new dwellings had to be supplied quickly. The greatest part of the 250,000 population increase from 1941 to 1951 took place in the post-war period. The urban growth during that period took the form of a concentric pattern of accretion, clinging to the already built-up sections, as shown in Figure 2. The houses built then were predominantly of the row type, two and three storeys high, but on large lots, and intermingled with single-family dwellings. This is further witnessed by the fact that the gross density of population in the areas built during the 1945–1950 period is generally three times lower than in those built before the war. The rapid urban growth of that period extended over a large area, and land available for construction soon became scarce; this prompted a wave of land speculation throughout an area of some 100,000 acres, in the western and eastern parts of the island of Montreal, on Ile Jésus and on the south shore. (Land under speculation, for the present purpose, is understood as land owned or under short-term (less than two-year) options by non-farmers who are engaged in the build-

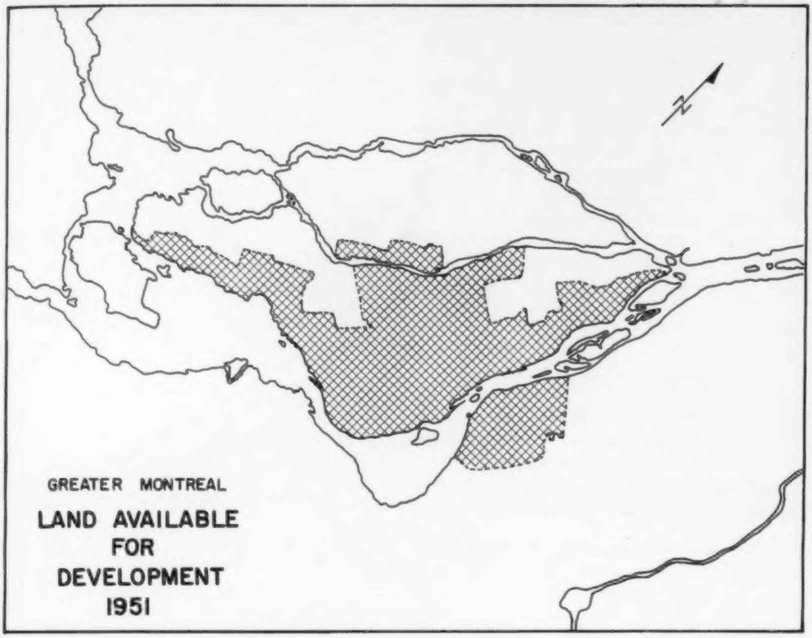

FIGURE 3

ing trade directly or indirectly (land companies, real estate companies, etc.) and who have stated their intention to develop the land within five years.)

1951–1956 PHASE OF SUBURBAN GROWTH: THE RADIAL-NODAL PATTERN

By 1951, land speculation was ripe and a series of new urban municipalities—some 15 of them—were born. These 15 municipalities nearly doubled the total area of Greater Montreal, adding some 63,000 acres to the 65,000 acres which were available in 1945, making a total of 128,000 acres in 1951 (Figure 3). These new additions were all concentrated on the bridge-heads and along the main routes leading out of the city. The suburban growth thus took the form of radial growth. However, not all of those areas were developed from 1950 to 1955. Urban growth during that period continued to have a concentric form ringing the built-up sections in an accretion pattern. Most important, however, it also moved into new areas along the radial lines of transportation, but not in a progressive fashion; rather it grew haphazardly around small, existing village nuclei, thus taking the form of a radial-nodal pattern of growth (Figure 4).

In the small nuclei, the growth also took a concentric form with long spaghetti-shaped monotonous streets of identical single-family houses.

During this period, ample land being available for urban growth, very little speculation took place.

1956–1958 PHASE OF SUBURBAN GROWTH: RADIAL-INTERNODAL PATTERN

By 1956, only three municipalties had joined the others, adding a mere 11,000 acres to the previous 128,000 (Figure 5).

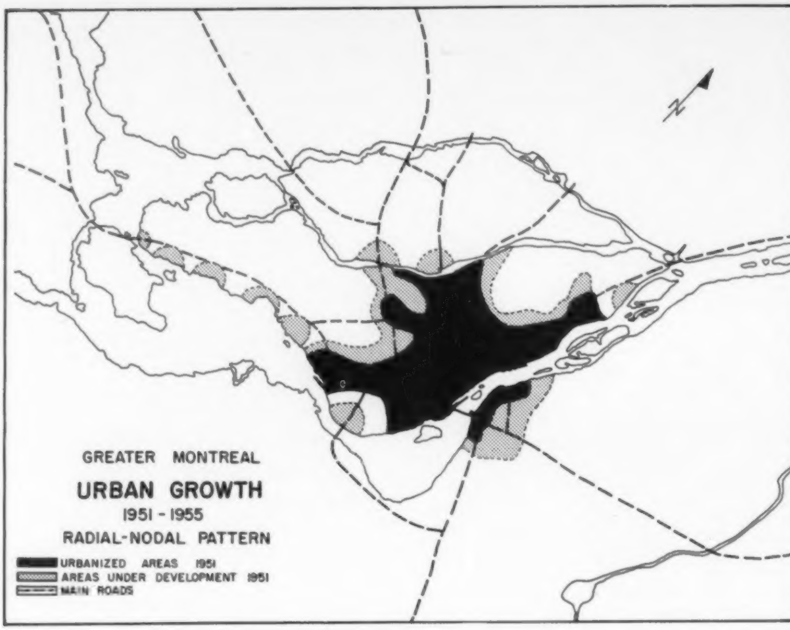

FIGURE 4

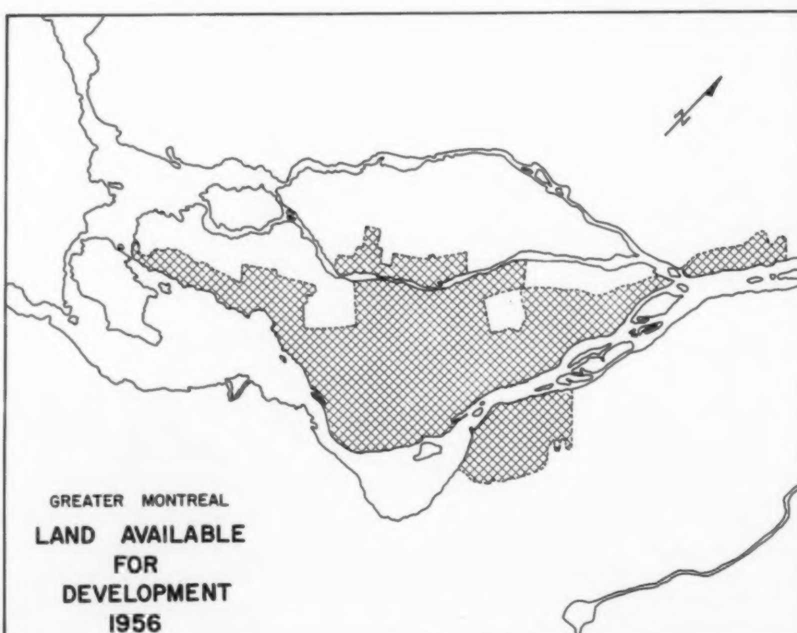

FIGURE 5

From 1956 to 1958, urban growth continued to take place in the same areas as for the period 1950 to 1955 but in a slightly different manner. The nuclei enlarged to such a point that they all joined together, thus giving a radial-internodal pattern of growth (Figure 6). The end result was that the highways of yesterday became long tunnels flanked by row upon row of houses, extending for some 15 miles outside the city.

THE 1958 WAVE OF LAND SPECULATION

During both phases of suburban growth, from 1950 to 1955 and from 1956 to 1958, an average of some 7,000 acres of land were used yearly for urban growth, at a density of 12 to 15 persons per acre. The amount of land available for construction was being gradually reduced to a point where, in 1958, there were only some 35,000 to 40,000 acres of land still available, an area sufficient for only five years of growth at the then current rate. This shortage of land, the speed of growth, and the rising cost of land within the urbanized areas spurred a wave of land speculation of considerable magnitude. Early in 1959, a survey conducted by the Central Mortgage and Housing Corporation showed that some 620,000 acres of land were held directly or indirectly by speculators around Montreal (Figure 7). This wave of land speculation extended as far as 50 miles away from the city towards the resort area of the Laurentians after the construction of a major auto-route, and along the south shore of the St. Lawrence River up to Sorel, because of the construction of the St. Lawrence Seaway. In some areas, as the map indicates, as much as ninety-five per cent of the land was held by speculators, while, in other areas which lacked the speculative values sought, it was as low as forty per

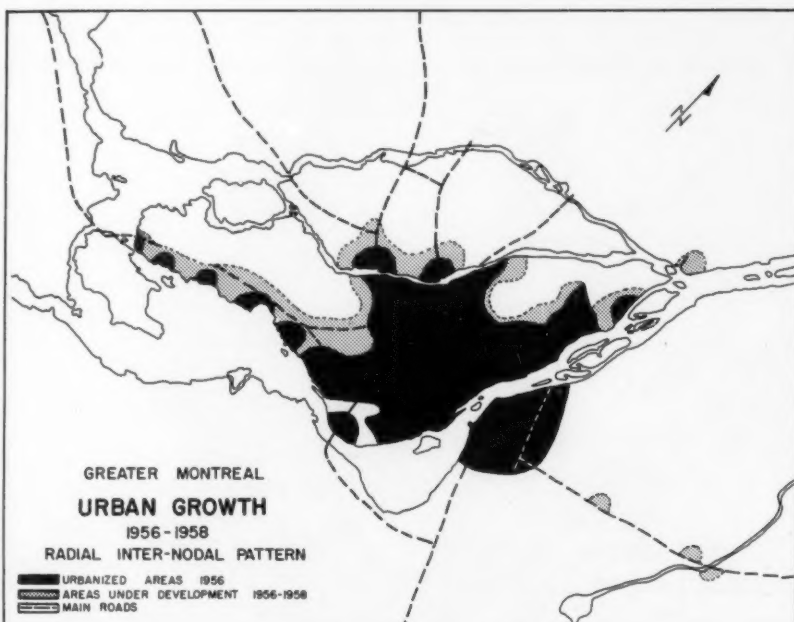

FIGURE 6

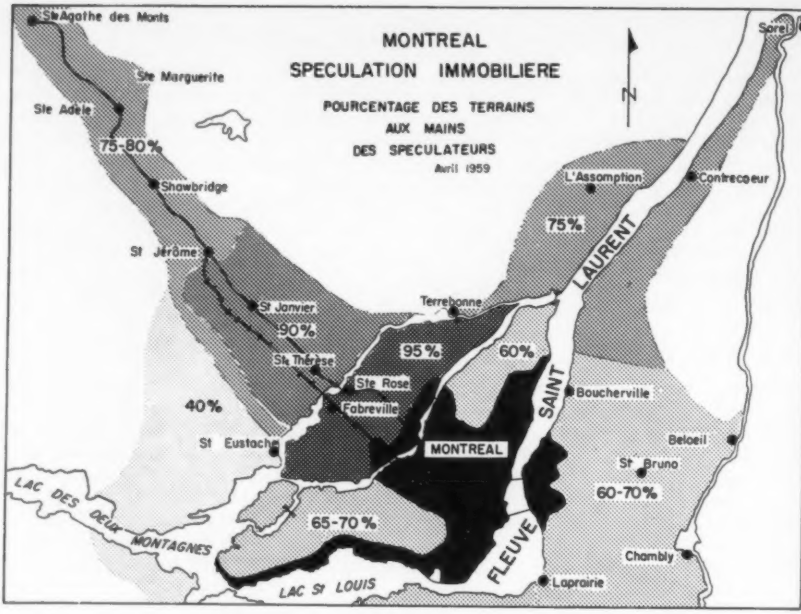

FIGURE 7

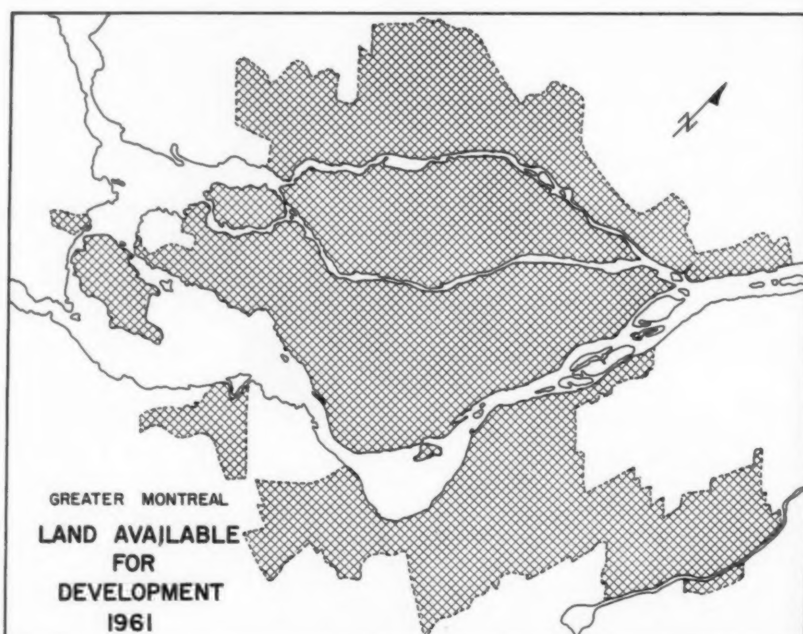

FIGURE 8

cent. The pressures arising from the diminution in the quantity of land immediately available for residential development, the agitation of speculators, the tendency of people to move further out into new towns, the industrial decentralization, and the ambitions, or should one say megalomania, of municipal officials were all factors which prompted a large number of rural municipalities to organize themselves for urban growth. The land available for immediate or near-future construction has increased from 35,000 acres in 1958 to 350,000 acres today (Figure 8). Nearly fifty new municipalities, representing roughly 296,000 acres of land, have been organized since 1958. In the first five months of this year alone, over 100,000 acres of land have been added to the Greater Montreal area. This trend is further evidenced by the fact that the Dominion Bureau of Statistics, in revising its definition for Metropolitan Montreal for its 1961 decennial census, now includes 83 municipalities instead of the 46 of 1951.

ACTUAL PHASE OF SUBURBAN GROWTH: DISORDERLY WIDESPREAD DISPERSAL

The pattern of urban growth consequent to this wave of land speculation is one that can be called "disorderly widespread dispersal" (Figure 9). Urban growth now takes place partly in the urbanized areas through the filling-up process and partly in a series of small nuclei dispersed all over the Montreal region, in new municipalities often created on the spur of the moment. In fact, while in 1955 a mere two per cent of the total housing starts in Greater Montreal were located in these outer suburbs, in 1960 thirteen per cent of the total housing starts took place there. This trend is revealed still more strongly when population figures are used.

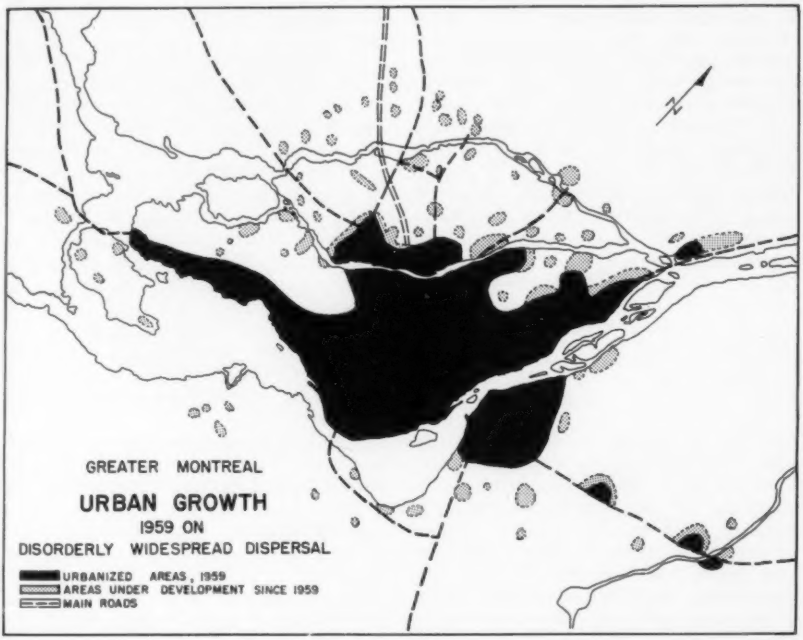

FIGURE 9

The pre-1950 Greater Montreal area absorbed forty-three per cent of the total population increase, but the inner suburbs, developed since 1951, absorbed twenty-eight per cent of the total population increase in the period from 1958 to 1960. From 1950 to 1955, this share had barely exceeded ten per cent.

The size of these outer suburbs, the new nuclei, because of their large number, is not comparable to that of the nuclei which were formed in the previous phases of urban growth. In this most recent pattern, the nuclei are limited in size, sometimes numbering only 50 to 100 houses. Of course, the intent of the promoters and of the municipal officials is to develop these micro-nuclei to the same size as those of the previous eras. But, in the 1951–1955 phase of growth, the number of nuclei was limited to only some 15 or 20; today there are more than a hundred, and new ones are being formed continually.

Within the large area of land available for immediate urban development, some 450,000 acres, there are only about 100,000 acres which are actually built up; thus enough land is left for urban development for another fifty years at the present rate of growth, assuming that the present low density of growth will be maintained, which is improbable, since signs of greater density development can be discerned already. This large area of land available for development does not need to be considered as an evil in itself. It is an evil at the present time, however, in Montreal, because of the disorder and the lack of co-ordination in current land-use practices.

THE FUTURE

What will happen in the future? It is possible that all of the nuclei will continue to grow at the same rate simultaneously. If such should be the case, none of them will be able to attain a reasonable or optimum size within the near future. All will then have to face considerable fináncial difficulties, among many other problems. The authorities in one of the new nuclei—and it happens to be perhaps the most successful—this year put out for the first time a complete tax roll and discovered to their horror that the tax bill they were obliged to send to home-owners of the low-cost houses amounted to between $500 and $600 for a $12,000 to $13,000 bungalow. And this is just the beginning. Furthermore, this municipality has developed a mere five to six per cent of its total territory in the last three years. If a reasonable and economically viable expansion is to take place, major capital expenditures will have to be faced. Is industrial development the answer? Not in this particular municipality, since its location is not advantageous for industrial enterprises which have hundreds of better sites at their disposal, at the moment at least.

Of course, it is the current practice that every single nucleus of development has its industrial zone, or, to put it in a more modern phrase, its "industrial park." Theoretically, this is very sound, but the end result is a quite phenomenal chaos when 100 municipalities do exactly the same thing at the same time and without a regional plan.

While it is possible that an even growth of the more than 100 nuclei will occur, it is highly improbable that this will be the case. It is clear that only fifteen to twenty per cent of the land which has become available for construction will be used for all possible purposes in the process of urban growth over the next ten years. A selection will thus be made; some areas will be privileged in relation to others. The choice will not be the effect of chance, that is, not more than the present shape of the urbanized area is the effect of chance. The type, direction, as well as the size of the new towns will bear a direct relationship to the values, attitudes, and behaviour of the community.

If such is the case, the nuclei which will be chosen may well be successful economically and socially. The others, the larger in number, not so chosen, will meet with bankruptcy both financially and socially. While the successful nuclei will boom, the unsuccessful ones will stand as groups of 50, 100, or 150 houses alone in the middle of fields without social and institutional facilities near by. One new municipality, for instance, has installed

water and sewer services throughout the municipality; it has built a sewage treatment plant, has opened streets, and has even built a golf course for the future residents. However, the promoters have not built a single house, as yet. If this nucleus meets with success, there will be no problem. If it fails, the one or two million dollars financial burden of capital expenditures would have to be supported by as few as 100 or 150 home-owners. This would automatically mean bankruptcy.

WHAT CAN BE DONE?

What can be done before it is too late. Many things, it seems, but I feel strongly that there are two in particular. First, the large lenders, banks, insurance companies, and the federal government through the Central Mortagage and Housing Corporation will have to direct their lending policy in order to avoid further spoiling, and in order to build healthier communities, both socially and economically.

Secondly, and most important, the Quebec provincial government will have to establish a regional planning policy throughout the entire province, but most particularly in the Greater Montreal area. So far, nothing, or practically nothing, has been done about it. The embryo of metropolitan government is far from being sufficient. Even if it had more powers and means, it still would not be efficient within the spirit of the Act which established it. The most serious problems to be faced in the very near future, today for that matter, are not so much in the nature of metropolitan problems as in the nature of regional problems. The municipalities, with their quite normal individualistic point of view, cannot do it alone. It is the duty of the provincial government to face up to this most serious and urgent problem.

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2. Montrealers call east what is in fact north. The same error applies to the other cardinal points. In order to avoid confusion, the cardinal points used by Montrealers are given here.
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RÉSUMÉ

Montréal, comme toutes les autres agglomérations métropolitaines importantes d'Amérique du Nord, a subi une intense croissance suburbaine depuis la fin de la Seconde Guerre Mondiale. L'expansion montréalaise s'est faite de quatre façons différentes durant les quinze dernières années.

D'abord, de 1945 à 1951, on a pu noter un rapide développement circulaire d'allure concentrique. De 1951 à 1956, l'expansion eut lieu, loin du centre, le long des principales lignes de transports, produisant ainsi un arrangement radié et nodulaire. Durant la courte période qui suivit, de 1956 à 1958, la croissance se poursuivit de façon intercalaire. Depuis 1959, ce fut la dispersion désordonnée.

Des facteurs divers expliquent ces formes différentes de développement suburbain : les caractéristiques physiques et sociales particulières à la région de Montréal, le morcellement des territoires municipaux, la disponibilité inégale des services et la tendance de l'industrie à la décentralisation sont les principaux.

Plus récemment, particulièrement en 1957–8, deux vagues de spéculation massive sur les terrains exercent sans doute le maximum d'influence sur le mode présent de croissance de Montréal.

GEOMETRIC PROJECTIONS OF THE SPHERE AND THE SPHEROID

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University of California at Los Angeles

1. INTRODUCTION

(1) *Cartography as Map Preparation vs. Data Processing*

Cartographers hitherto have not been much concerned with geometric (or perspective) projections because of their relative lack of interesting properties in comparison with analytic projections. By this is meant that about the only outstanding feature of geometric projections is that they are all azimuthal maps. Nearly all other properties are lost in the sense that they vary drastically from one geometric projection to another. The cartographer's lack of interest in this class of projections is perhaps a natural corollary to the traditional role which he assumes—that of a technician preparing a particular map for a particular purpose. The emphasis here is presumably on the end product (i.e. the prepared map) of a highly complex and technical process known as cartography.

The advent of high-speed computers has created a new function for cartography—that of data-processing.[1] Maps are now considered as storage units of various types of geographic information, the most important of which is of course locational (or spatial) information. Here, the emphasis is no longer on the maps themselves but rather on the relation between a pair of these. For example, one may be interested in knowing how easily and rapidly information may be fed into or extracted from a storage unit like a map or between two such units. It is in the light of this new function that geometric projections have begun to attract a growing interest in both theory and application.

(2) *Role of Geometric Projections in Data Processing*

Data-processing necessitates data to be converted and manipulated in some processed form which is compatible with rapid execution of arithmetic operations on the computer. By this requirement geometric projections are far superior to analytic projections since projective methods alone would suffice and these require merely simple arithmetic operations. For a large class of data-processing problems, experience has shown that information can be phrased quite successfully in terms of purely projective or topological rather than analytic properties.[2] Even where relatively faithful representation to the naked eye is important, the computer may be so programmed as to produce such display (presumably an analytic projection) on demand, while internally it uses geometric projections for processing and computation.

(3) *Geometric Projections as Point vs. Co-ordinate Transformations*

From a mathematical standpoint, all geometric projections are projective maps and as such may be considered as either point or co-ordinate transformations.[3]

Traditionally, they are studied as point transformations under which a certain point set (e.g. a sphere or a spheroid) in space is mapped or moved onto another set.[4] The natural tool for this approach is spherical trigonometry. Unfortunately, visualization of movement of points becomes rather difficult for projection surfaces which are non-planar as well as for planes which are tilted with respect to the centre of projection. Each new projection has to be attacked afresh and there appears to be little unity in the treatment of them all.

In this article, geometric projections are studied from the standpoint of co-ordinate transformations. Points are generally considered fixed, only their labels may change. A change in labels is induced by a change in bases or co-ordinate systems, and the central idea is the preservation of incidence relations like collineation, correlation, etc. Hence, the natural tool for this approach is matrix algebra. All mapping equations can be easily derived from this general principle which provides not only a unified theory for all geometric projections but a ready generalization to tilted planes or non-planar projection surfaces. Only the important results from a previous study[5] and a few new observations (e.g. 2(4)) will be summarized here.

2. GEOMETRIC PROJECTIONS OF THE SPHERE

(1) *Notations*

E^n denotes n-dimensional Euclidean space. Lower case Greek letters or Latin letters with superscripts denote real numbers (e.g. λ, x^2 in E^1); lower case Latin letters without superscripts will mean, however, points in E^3 whereas capital Latin letters denote sets of points in E^3. $\{\vec{e}_\alpha\}$, $\alpha = 1,2,3$, denotes a rectangular frame of co-ordinate vectors at the origin o of E^3, in terms of which an arbitrary vector $\vec{x}$ has the label (x^1, x^2, x^3). For any pair of vectors $\vec{x}, \vec{y}$ with labels (x^1, x^2, x^3), (y^1, y^2, y^3), the scalar product between them is defined by

$$(2.1.1)\quad [\vec{x}, \vec{y}] = \Sigma_{\alpha=1}^{3} x^\alpha y^\alpha = x^1 y^1 + x^2 y^2 + x^3 y^3$$

$\vec{x} \perp \vec{y}$ if and only if $[\vec{x}, \vec{y}] = 0$, and $\vec{x} \perp H$ if and only if $\vec{x} \perp \overrightarrow{qp}$ for every pair of points p, q in H. For any vector $\vec{x}$, its length is defined by

$$(2.1.2)\quad ||\vec{x}|| = [\vec{x}, \vec{x}]^{\frac{1}{2}}$$

In particular,

$$(2.1.3)\quad [\vec{e}_\alpha, \vec{e}_\beta] = \delta_{\alpha\beta} = \begin{cases} 1 & \text{if } \alpha = \beta \\ 0 & \text{if } \alpha \neq \beta \end{cases}$$

Any triple of vectors $\{\vec{v}_\alpha\}$, $\alpha = 1,2,3$, satisfying (2.1.3) is said to form an orthonormal basis.

The unit sphere S is the set of all points p in E^3 such that $||\overrightarrow{op}|| = 1$, and these can be parametrized by

$$(2.1.4)\quad \begin{cases} x^1 = \cos\phi\cos\bar{\lambda} \\ x^2 = \cos\phi\sin\bar{\lambda} \\ x^3 = \sin\phi \end{cases} \quad (-\pi/2 \leqq \phi \leqq \pi/2, 0 \leqq \bar{\lambda} < 2\pi)$$

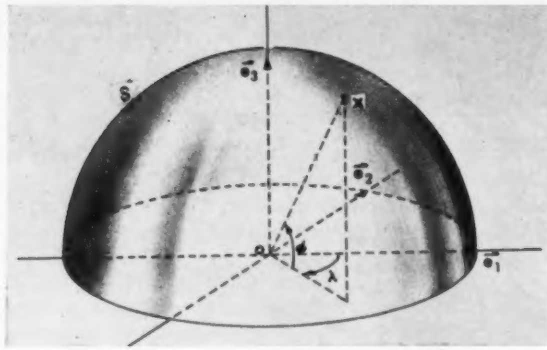

FIGURE 1

where ϕ is the latitude of p defined by the angle from the equatorial plane spanned by $\vec{e}_1$, $\vec{e}_2$ to $\overrightarrow{op}$, and $\bar{\lambda}$ is the longitude of p defined by the angle from the plane containing $\vec{e}_1$, $\vec{e}_3$ to that containing p and $\vec{e}_3$. The endpoint of $\vec{e}_3$ is the north pole of S, and that of $\vec{e}_1$ determines the 0° meridian (Figure 1). The concern here is mainly with points in the western hemisphere of S, so that a change of parameters $\lambda = -\bar{\lambda}$ will be made once for all, and λ now means longitude west.

(2) *Definition of Geometric Projections*

Let a, b be two fixed points in E^3. A ray from a through b is the set of all points $\mu\overrightarrow{ab}$, $\mu \geqq 0$. Let a fixed point z in E^3 and a fixed set A in E^3 be given. Then the set of all rays $\mu\,\overrightarrow{za}$ for a in A is called a cone through A with apex z, written $C(z, A)$. If D is any other set in E^3 such that the common portion of $C(z, A)$

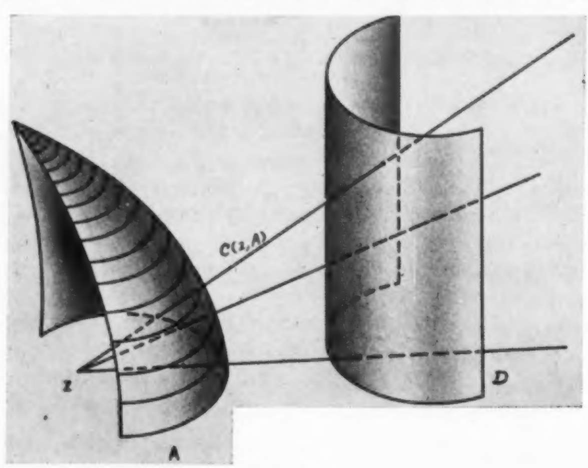

FIGURE 2

and D, written $C(z, A) \cap D$, is not void, then a geometric projection from z of A to D is the triple (z, A, B) where $B = C(z, A) \cap D$ (Figure 2). While this definition covers all geometric projections, it will be applied only to cases where A is a subset of a sphere or spheroid and D is a developable surface.

(3) *Centrally Symmetric Geometric Projections*

Let A be a subset of S, D a plane in E^3. A geometric projection (z, A, B) is called centrally symmetric if the apex z of $C(z, A)$, the origin o of E^3 and the contact point x_0 between S and D are collinear. In such case, an orthonormal basis $\{\vec{v}_\alpha\}$, $\alpha = 1, 2, 3$, may be chosen for the (rectangular) mapping co-ordinates on D as follows: First, $\{\vec{v}_\alpha\}$, $\alpha = 1, 2, 3$, is obtained from $\{\vec{e}_\alpha\}$, $\alpha = 1,2,3$, by a rotation

$$(2.3.1) \quad \|\vec{v}_1\vec{v}_2\vec{v}_3\| = \|\vec{e}_1\vec{e}_2\vec{e}_3\| \begin{Vmatrix} \sin\lambda_0 & -\sin\phi_0\cos\lambda_0 & \cos\phi_0\cos\lambda_0 \\ \cos\lambda_0 & \sin\phi_0\sin\lambda_0 & -\cos\phi_0\sin\lambda_0 \\ 0 & \cos\phi_0 & \sin\phi_0 \end{Vmatrix}$$

where (ϕ_0, λ_0) denote the latitude and the longitude of the map centre (i.e. contact point x_0 between S and D). Then $\{\vec{v}_1, \vec{v}_2, (1 + \psi)\vec{v}_3\}$ is the co-ordinate system chosen for D where $(1 + \psi)$ is the distance between z and D (Figure 3).

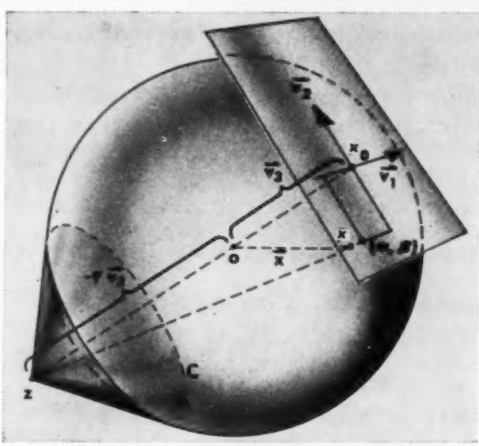

FIGURE 3

Now, for any vector $\vec{x}$ whose endpoint x with (ϕ, λ) lies on S the following relation must hold:

$$(2.3.2) \quad \zeta(\vec{x} + \psi\vec{v}_3) = (1 + \psi)\vec{v}_3 + \alpha\vec{v}_1 + \beta\vec{v}_2$$

for some scalars α, β, and ζ. In component form, (2.3.2) gives three linear restrictions on the three unknowns α, β, and ζ, and straightforward calculation gives the desired mapping co-ordinates

$$(2.3.3)\quad \begin{cases} \alpha = \dfrac{(1+\psi)\cos\phi\sin(\lambda_0-\lambda)}{\psi+\sin\phi_0\sin\phi+\cos\phi_0\cos\phi\cos(\lambda_0-\lambda)} \\ \beta = \dfrac{(1+\psi)[\cos\phi_0\sin\phi-\sin\phi_0\cos\phi\cos(\lambda_0-\lambda)]}{\psi+\sin\phi_0\sin\phi+\cos\phi_0\cos\phi\cos(\lambda_0-\lambda)} \end{cases}$$

on the projection plane D tangent to S at x_0.

In (2.3.3) ψ is a parameter denoting the distance of z from D. It is clear that no generality is lost by taking D tangent to S since otherwise one will obtain a map homothetic to this particular one.[6] For centrally symmetric geometric projections, (2.3.3) therefore gives the most general mapping equations.

For $\psi = 0$, z coincides with the origin o of E^3 giving the gnomonic projection; for $\psi = 1$, z becomes the diametrically opposite point to x_0, the contact point between S and D, giving the stereographic projection. It is interesting to note that for $\psi > 1$ one gets a map which is frequently associated with photogrammetry in satellite surveillance.

(4) *Tilted or Non-Centrally Symmetric Geometric Projections*

When the projection plane D is not normal to the line containing z and o, a "tilted" geometric projection results. The resulting map differs from a centrally symmetric geometric projection by a rotation and/or a scale magnification of the bases chosen. More specifically, if $\{\vec{w}_\alpha\}$, $\alpha = 1, 2, 3$, is an orthonormal basis such that $\vec{w}_1$, $\vec{w}_2$ determine the directions of the rectangular co-ordinates on D, tilted with respect to the half-line $\mu\, \vec{zo}$, $\mu \geqq 0$, then $\{\vec{w}_\alpha\}$ and $\{\vec{v}_\alpha\}$ in (2.3.1) differ by a rotation

$$(2.4.1)\quad ||\vec{w}_1\vec{w}_2\vec{w}_3|| = ||\vec{e}_1\vec{e}_2\vec{e}_3|| \begin{Vmatrix} \cos\alpha_1 & \cos\beta_1 & \cos\gamma_1 \\ \cos\alpha_2 & \cos\beta_2 & \cos\gamma_2 \\ \cos\alpha_3 & \cos\beta_3 & \cos\gamma_3 \end{Vmatrix}$$

where the last matrix contains the direction cosines of the basis vectors $\{\vec{w}_\alpha\}$, $\alpha = 1,2,3$, with respect to the basis vectors $\{\vec{v}_\alpha\}$, $\alpha = 1,2,3$. Depending on the position of D with respect to S, another scale magnification may be required.

(5) *Conic or Cylindrical Geometric Projections*

An extension of the projective method to the case where the projection surface is either a cone or a cylinder is relatively straightforward, although the resulting mapping equations need not always be simple. In any case, an application of the fundamental principle on the preservation of incidence relation will immediately yield the desired mapping equations. While the proofs[7] are not presented, the following results may be worth noting.

If a cylinder is tangent to S along the equator ($\phi = 0$), and x_0 with (ϕ_0, λ_0) is the map centre, then the mapping equations are given by

$$(2.5.1)\quad \begin{cases} \alpha = \lambda_0 - \lambda \\ \beta = \tan\phi - \tan\phi_0 \end{cases}$$

If the cylinder is tangent to S along a meridian ($\lambda = \lambda_0$), then the mapping equations are given by

$$(2.5.2)\quad \begin{cases} \alpha = \tan\theta \\ \beta = \phi' - \phi_0 \end{cases}$$

where

$$(2.5.3)\quad \begin{cases} \theta = \sin\phi \sin\phi' + \cos\phi \cos\phi' \cos(\lambda_0 - \lambda) \\ \phi' = \arctan\,[\tan\phi \sec(\lambda_0 - \lambda)] \end{cases}$$

If a secant cone cuts S in two standard parallels ϕ_1, ϕ_2, and x_0 with (ϕ_0, λ_0) is the map centre, then the mapping equations are given by

$$(2.5.4)\quad \begin{cases} \alpha = (\zeta^2 + \xi^2 - 2\zeta\xi \sin\phi)^{\frac{1}{2}} \sin[(\lambda_0 - \lambda)\sin\omega] \\ \beta = (\zeta_0^2 + \xi^2 - 2\zeta_0\xi \sin\phi_0)^{\frac{1}{2}} - (\zeta^2 + \xi^2 - 2\zeta\xi \sin\phi)^{\frac{1}{2}} \\ \qquad \cos[(\lambda_0 - \lambda)\sin\omega] \end{cases}$$

where

$$(2.5.5)\quad \begin{cases} \zeta = \sin(\phi_2 - \phi_1)[\sin(\phi - \phi_1) + \sin(\phi_2 - \phi)]^{-1} \\ \xi = \sin(\phi_2 - \phi_1)(\cos\phi_1 - \cos\phi_2)^{-1} \\ \zeta_0 = \sin(\phi_2 - \phi_1)[\sin(\phi_0 - \phi_1) + \sin(\phi_2 - \phi_0)]^{-1} \\ \omega = \arctan\,[(\cos\phi_1 - \cos\phi_2)(\sin\phi_2 - \sin\phi_1)^{-1}] \end{cases}$$

When one standard parallel is used, the desired mapping equations can be obtained from above by letting ϕ_2 approach ϕ_1 and using l'Hospital's rule to evaluate the limits of the corresponding indeterminate form.

(6) *Transformations between Geometric Projections*

As stated above, the primary feature of geometric projections is their relative simplicity and amenability to numerical calculations. By the same general principle on incidence relation, transformations between any pair of geometric projections may be readily obtained. Detailed results as well as inverses to all above mapping equations may be found in a previous study, which also presents many practical applications of the general theory.[8]

3. GEOMETRIC PROJECTIONS OF THE SPHEROID

(1) *Parametrization of the Spheroid*

The theory developed above may easily be extended to the spheroid except that a convenient parametrization for it is first needed. Let H denote an oblate spheroid parametrized as follows:

$$(3.1.1)\quad \begin{cases} x^1 = \alpha\cos\omega\cos\lambda \\ x^2 = -\alpha\cos\omega\sin\lambda \quad (-\pi/2 \leqq \omega \leqq \pi/2, 0 \leqq \lambda < 2\pi) \\ x^3 = \beta\sin\omega \end{cases}$$

where α, β are respectively the lengths of the semi-major and the semi-minor axis of H. Actually, only the ratio α/β is important. The geometric meaning of the parameter ω will now be described.

Let $x = (x^1, x^2, x^3) = (\alpha\cos\omega, 0, \beta\sin\omega)$ lie on the meridian ellipse E_0 of H at zero longitude. The angle ψ defined by

$$(3.1.2)\quad \tan\psi = x^3/x^1 = \beta\sin\omega/\alpha\cos\omega = (\beta/\alpha)\tan\omega$$

is called the geocentric latitude of a point x on H. On the other hand, E_0 satisfies the equation

$$(3.1.3) \quad (x^1/\alpha)^2 + (x^3/\beta)^2 = 1$$

so that the tangent to E_0 at x has slope $dx^3/dx^1 = -(\beta^2 x^1/\alpha^2 x^3) = -(\beta/\alpha)\cot \omega$ and hence the normal to E_0 at x has slope

$$(3.1.4) \quad \tan \phi = (\alpha/\beta)\tan \omega$$

where ϕ is called the geodetic latitude of the point x on H. From (3.1.2) and (3.1.4), it follows $\tan^2\omega = \tan \psi \tan \phi$, so $\tan \omega$ is the geometric mean of $\tan \psi$ and $\tan \phi$.

Choosing a basis or co-ordinate system for a plane D in E^3 onto which H will be projected, let $\{\vec{e}_\alpha\}$, $\alpha = 1,2,3$, be the natural orthonormal basis described in (2(1)) and $x_0 = (x_0^1, x_0^2, x_0^3)$ be a fixed point on H. The unit normal

$$\vec{u}_3 = \Sigma^3_{\sigma=1}(\partial f/\partial x^\sigma)_{x=x_0}\vec{e}_\sigma$$

to H at x_0 has components

$$(3.1.5) \quad (\rho\beta \cos \omega_0 \cos \lambda_0, -\rho\beta \cos \omega_0 \sin \lambda_0, \rho\alpha \sin \omega_0)$$

where $\rho = (\beta^2\cos^2\omega_0 + \alpha^2\sin^2\omega_0)^{-\frac{1}{2}}$ and

$$(3.1.6) \quad f(\vec{x}) = (x^1/\alpha)^2 + (x^2/\alpha)^2 + (x^3/\beta)^2 - 1 = 0$$

is the equation for H. From (3.1.4) it is deduced

$$(3.1.7) \quad \begin{cases} \cos \phi = (1 + \tan^2 \phi)^{-\frac{1}{2}} = \rho\beta \cos \omega \\ \sin \phi = (1 - \cos^2 \phi)^{\frac{1}{2}} = \rho\alpha \sin \omega \end{cases}$$

so that (3.1.5) can be simplified into $(\cos \phi_0 \cos \lambda_0, -\cos \phi_0 \sin \lambda_0, \sin \phi_0)$ which coincides with $\vec{v}_3$ in (2.3.1). $\vec{u}_1$, $\vec{u}_2$ are again chosen as $\vec{v}_1$, $\vec{v}_2$ in (2.3.1) so that the only difference between the spheroid case and the sphere case is that different parameters and different labels are used.[9] In terms of $\{\vec{u}_\alpha\}$, $\alpha = 1,2,3$, an arbitrary vector $\vec{x}$ with endpoint x on H can be written as

$$\vec{x} = \Sigma^3_{\sigma=1} \xi^\sigma \vec{u}_\sigma \text{ where}$$

$$(3.1.8) \quad \begin{cases} \xi^1 = \alpha \cos \omega \sin(\lambda_0 - \lambda) \\ \xi^2 = \beta \sin \omega \cos \phi_0 - \alpha \cos \omega \sin \phi_0 \cos(\lambda_0 - \lambda) \\ \xi^3 = \beta \sin \omega \sin \phi_0 + \alpha \cos \omega \cos \phi_0 \cos(\lambda_0 - \lambda) \end{cases}$$

For $\lambda = \lambda_0$, $\omega = \omega_0$, (3.1.8) reduces to

$$(3.1.9) \quad \begin{cases} \xi_0^1 = 0 \\ \xi_0^2 = \beta \sin \omega_0 \cos \phi_0 - \alpha \cos \omega_0 \sin \phi_0 \\ \xi_0^3 = \beta \sin \omega_0 \sin \phi_0 + \alpha \cos \omega_0 \cos \phi_0 \end{cases}$$

where $x_0(0,\xi_0^2,\xi_0^3)$ corresponds to the map centre on the projection plane D at distance h from H.[10]

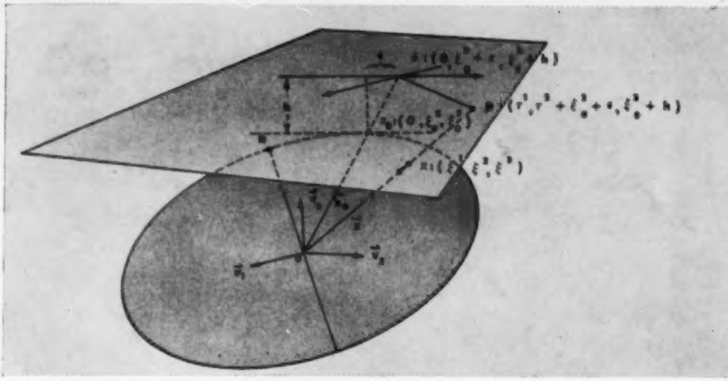

FIGURE 4

(2) Gnomonic Projection of the Spheroid

In this case the centre of projection z is at the origin o of E^3 (Figure 4). The collineation of o, x, p gives

$$(3.2.1)\quad \frac{\tau^1 - 0}{\xi^1 - 0} = \frac{(\tau^2 + \xi_0^2 + \epsilon) - 0}{\xi^2 - 0} = \frac{(\xi_0^3 + h) - 0}{\xi^3 - 0}$$

whence

$$(3.2.2)\quad \begin{cases} \tau^1 = (h + \xi_0^3)\xi^1/\xi^3 \\ \tau^2 = (h + \xi_0^3)\xi^2/\xi^3 - (\xi_0^2 + \epsilon) \end{cases}$$

where all quantities are given by (3.1.8) and (3.1.9) and

$\epsilon = h(\xi_0^2/\xi_0^3)$.

A straightforward substitution yields the mapping co-ordinates:

$$(3.2.3)\quad \begin{cases} \tau^1 = \dfrac{(h + \xi_0^3)\alpha \cos\omega \sin(\lambda_0 - \lambda)}{\beta \sin\omega \sin\phi_0 + \alpha \cos\omega \cos\phi_0 \cos(\lambda_0 - \lambda)} \\ \tau^2 = \dfrac{(h + \xi_0^3)\alpha\beta[\cos\omega_0 \sin\omega - \sin\omega_0 \cos\omega \cos(\lambda_0 - \lambda)]}{\xi_0^3[\beta \sin\omega \sin\phi_0 + \alpha \cos\omega \cos\phi_0 \cos(\lambda_0 - \lambda)]} \end{cases}$$

where $\xi_0{}^3$ is as defined in (3.1.9).

(3) Stereographic Projection of the Spheroid

In this case, z is at

$-x_0 = (0,\ -\xi_0^2,\ -\xi_0^3)$

(Figure 5). The collineation of $-x_0$, x, p gives

$$(3.3.1)\quad \frac{\sigma^1 - 0}{\xi^1 - 0} = \frac{(\sigma^2 + \xi_0^2 + \epsilon) - (-\xi_0^2)}{\xi^2 - (-\xi_0^2)} = \frac{(\xi_0^3 + h) - (-\xi_0^3)}{\xi^3 - (-\xi_0^3)}$$

whence

$$(3.3.2)\quad \begin{cases} \sigma^1 = (h + 2\xi_0^3)\xi^1/(\xi_0^3 + \xi^3) \\ \sigma^2 = (h + 2\xi_0^3)(\xi_0^2 + \xi^2)/(\xi_0^3 + \xi^3) - (2\xi_0^2 + \epsilon) \end{cases}$$

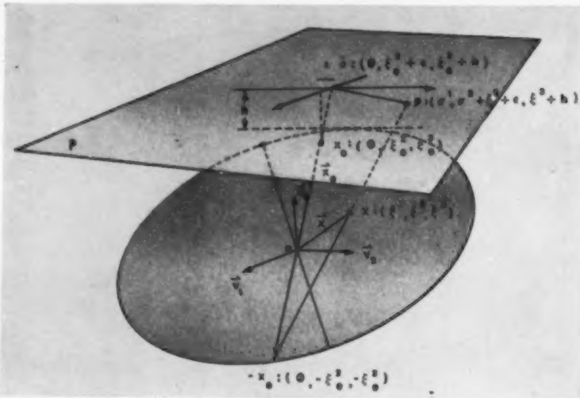

FIGURE 5

where $\epsilon = h(\xi_0^2/\xi_0^3)$

as before. Substitution of (3.1.8), (3.1.9) into (3.3.2) yields the mapping co-ordinates:

$$(3.3.3) \quad \begin{cases} \sigma^1 = \dfrac{(h + 2\xi_0^3)\alpha \cos\omega \sin(\lambda_0 - \lambda)}{\xi_0^3 + \beta \sin\phi_0 \sin\omega + \alpha\cos\phi_0 \cos\omega \cos(\lambda_0 - \lambda)} \\ \sigma^2 = \dfrac{(h + 2\xi_0^3)\alpha\beta[\cos\omega_0 \sin\omega - \sin\omega_0 \cos\omega \cos(\lambda_0 - \lambda)]}{\xi_0^3[\xi_0^3 + \beta\sin\phi_0 \sin\omega + \alpha\cos\phi_0\cos\omega\cos(\lambda_0 - \lambda)]} \end{cases}$$

(4) *Conic or Cylindrical Projection of the Spheroid*

The general theory developed here may also be readily extended to the case where D is a cone or a cylinder.[11] The resulting mapping equations are rather complicated and will not be presented here. However, the method for obtaining them is again straightforward.

4. SUMMARY

Geometric projections have become increasingly important for the purpose of processing geographic (locational) data. A general theory is presented here whereby all mapping equations may be simply derived from one fundamental principle, that of the preservation of incidence relation together with the choice of an appropriate mapping basis (i.e. co-ordinate system). This theory may be extended to "tilted" planes, cones or cylinders as projection surfaces as well as to the spheroid, although the resulting mapping equations need not always remain simple.

For data-processing, centrally symmetric, in particular gnomonic, projections, are the most efficient. However, parallel usage of more than one class of centrally symmetric projections is quite feasible and in many applications desirable. From a practical standpoint, only centrally symmetric projections prove convenient for processing geographic information even though the general theory may readily be extended to other cases.

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5. Cf. Kao, Geometric Projections.
6. Two maps are homothetic to each other if they differ by a scale magnification.
7. Cf. Kao, Geometric Projections, §4.
8. *Ibid.*, §§5 and 6 and *passim*.
9. In other words, the co-ordinate system on the projection plane may be chosen to be the same for the spheroid as for the sphere, i.e., $\{\vec{u}_\alpha\} = \{\vec{v}_\alpha\}$, $\alpha = 1,2,3$, although with respect to the natural basis $\{\vec{e}_\alpha\}$, $\alpha = 1,2,3$, they are different. This is the method of *repère mobile* by Elie Cartan which may also be used to derive analytic projections. Cf. Cartan, E.: *Leçons sur la géométrie des espaces de Riemann* (2nd ed.), Gauthier-Villars, Paris, 1951, chap. ix; Blaschke, Wilhelm: *Einführung in die Differentialgeometrie*, Springer-Verlag, Berlin, 1950, p. 12ff.; Willmore, T. J.: *An Introduction to Differential Geometry*, Clarendon Press, Oxford, 1959, pp. 294–9.
10. The lower case Latin letter h means a scalar in this case.
11. Cf. Melluish, *The Mathematics of Map Projections*.

RÉSUMÉ

Le développement du calcul par moyens électroniques très rapides a créé un nouveau rôle pour la cartographie; celui du traitement de l'information. L'importance des cartes, considérées individuellement, a diminué; on peut maintenant porter l'attention sur l'analyse des relations entre plusieurs données cartographiques. Pour exécuter ce travail, les projections géométriques sont très supérieures aux projections analytiques, puisqu'il devient nécessaire que les méthodes de projection puissent être adaptées à la rapidité des opérations arithmétiques du calculateur électronique.

Dans le passé, les projections géométriques ont été utilisées presqu'uniquement comme moyens de transport de points. Ainsi, un certain point à la surface d'une sphère ou d'un sphéroïde pouvait être projeté dans l'espace. Chaque projection était étudiée séparément et il était difficile, sinon impossible, de considérer les rapports entre projections d'un même groupe.

Dans cet article, l'auteur présente une théorie générale des projections géométriques par laquelle toute équation cartographique peut être dérivée d'un même principe fondamental : celui de la préservation d'une incidence continue des rapports entre les données cartographiques aussi bien que d'une méthode de représentation appropriée. Cette technique peut être appliquée à des surfaces de projection obliques, coniques ou cylindriques, de même qu'à un sphéroïde, de préférence à une sphère, pour la représentation du globe terrestre.

Pour le traitement de l'information cartographique, l'auteur suggère l'adoption d'un type particulier de projections géométriques, celui des projections à symétrie centrale qui, selon lui, sont les plus utiles. De ce groupe, les projections gnomoniques lui semblent les plus commodes. Néanmoins, la théorie générale qu'il présente dans cet article ne se limite pas à ces dernières et peut s'appliquer parallèlement à plus d'une catégorie de projections à symétrie centrale.

THE BONNECHERE CAVES, RENFREW COUNTY, ONTARIO: A NOTE

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THE BONNECHERE CAVES are situated by the village of Knightington, 5½ miles east of Eganville, Renfrew County. Here the Bonnechere River has cut a small gorge with rapids and waterfalls, (the "Fourth Chute"), through an outlier of Paleozoic limestones. The Caves are developed in the north wall of the gorge. The author visited them with a party of students from McMaster and Toronto Universities in September, 1960. A part of the system has been developed as a tourist attraction and we were indebted to the proprietor, Mr. Tom Woodward, for a fund of information and his enthusiastic guidance during our exploration. At the conclusion of the visit, it was felt that the Caves demonstrated, attractively and simply, many of the principles of limestone cavern development, thus justifying a note drawing attention to them. No dimensional measurements were taken during the visit, so that all that are quoted, and the sketch diagram, Figure 1, should be treated as very approximate.

SITE OF THE CAVES

The Bonnechere River above the Fourth Chute is of low gradient, flowing on a broad bench, (the Fourth Level, see Figure 1), cut in the limestone. At the Chute the river has incised the bench over a length of some 300 yards, reaching a maximum depth of fifty feet at the downstream end, whence it runs out over a second gentle reach. The limestone exposed is in the Mohawkian Series of the Ordovician and has been reported in detail by Kay.[1] The lower 30 feet is the Chaumont Limestone, the topmost member of the Black River Group. Overlying it along a well-marked contact are the basal beds of the *Rockland* Limestone, Trenton Group, completing the section.

The development of the caverns, and of waterfalls and flatter sections in the Chute, has been markedly controlled by the lithology of the *Chaumont*. In a geomorphic reference, this consists of regularly alternating groups of thin, weak beds and thicker, resistant beds, lying horizontally along the gorge. The "First," "Second," and "Third" levels are each floored by resistant beds which are being cut back by cap-rock recession. The Fourth Level has similarly been created by river stripping along shale bands in the *Rockland*, and is free of any till or sustained alluvial deposits. The bulk of cavern development has occurred between the Third and Fourth levels. The former is floored by massive, white limestone beds and the latter by calcite sandstones of the *Rockland*. Sandwiched between are the topmost beds of the *Chaumont*, 5 feet 4 inches of gray, platy limestone with intercalated shales.[1] The plates are thin and frequently fractured through, providing many planes for erosive attack.

The limestones are reported to dip northward at 10° in the north wall of the Chute,[1] but dips appeared to be lower than this back in the Caves. As the entrance parts of the cave system also trend northward, penetration by solvent waters from the river channel would be aided by a favourable structural gradient. The limestones are well jointed, the Chute itself following one major trend. There is no evidence of faulting.

The broad bench in the *Rockland* ends abruptly to the east (downstream) in a cliff face aligned roughly north-south. On the north bank this overhangs a tributary gorge, which has been excavated by effluent waters from the Caves to the level of the river below the Chute, The crest of the eastern wall of this gorge, though irregular, is a full 20 feet below the *Rockland* bench at the mouth, rising to meet it at the head. It is mantled with till, and so it

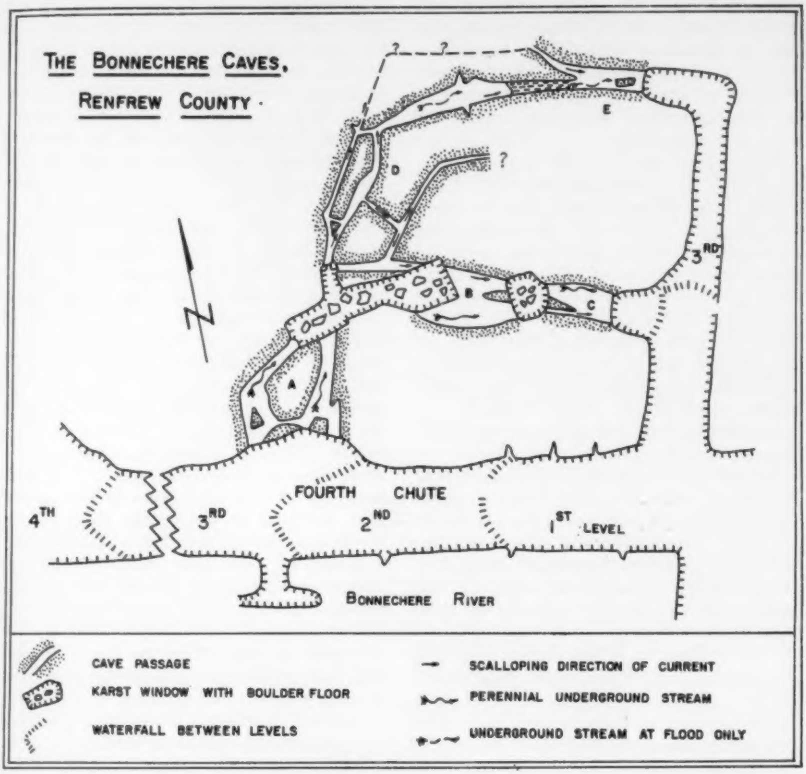

FIGURE 1

may be presumed that at the withdrawal of the last Wisconsin ice and any later marine, and so forth, inundations, a small erosional scarp was left upstanding here, over which the Bonnechere River fell and which it now incises (It is considered improbable that the Fourth Chute predates the last advance of the Wisconsin because the cliff top at its donwstream end, where the earliest incision would occur, is delicately castellated. Such forms could scarcely survive if over-ridden by ice.)

DEVELOPMENT OF THE CAVES

The Bonnechere Caves have developed as a result of the river's incision to the Third Level, which exposed the platy strata to lateral penetration by river water. They are therefore contemporary with the Chute, and of post-glacial age. Their function, throughout their history, has been to take a part of the drainage from the open channel into the north wall and to return it below the erosional scarp via the tributary gorge. That they should have developed at all, when drainage is more efficient and rapid down the Chute itself, may be attributed to highly favourable conditions of chemical composition, lithology, and jointing.

The Caves have a grid form with approximately 800–1000 feet of accessible passage ways, thus being the most extensive system reported in Ontario.[2] They are readily divisible into a major drainage line, A—B—C (on Figure 1), and a minor line A—D—E. Passage dimensions in the for-

mer vary from 10 to 20 feet in height and 8 to 25 feet in breadth. The principal passage in the minor line is 8 to 15 feet in height, 5 to 10 feet in breadth. Its lesser passages can only be entered by crawling or sidling, several becoming impassable after short distances.

The greater part of the system has a nearly flat floor profile in the white limestone of the Third Level. This has been breached through B—C, where the floor drops to an outlet at the Second Level. At the present time a small stream flows along this line throughout the year and the remainder of the cave is activated during flood periods. Following the bulk of its development, the system has been disrupted by the collapse of the roof in two places, creating fine "karst windows."

The history of the Bonnechere Caves may be divided into three phases:

Initiation. It is generally accepted that caverns in limestone are initially developed by the solutional action of CO_2 carried in meteoric waters, opening tubes of little more than capillary dimensions along lines of weakness. Certain authors consider that hydrostatic pressure is essential if deep penetration (in this case at least 80 yards to the outlets) is to be made; otherwise the initial tiny tubes may be readily blocked by the precipitation of calcite from a saturated solution.[3] This implies the Bonnechere system began when the bed of the river was being cut down into the platy strata, the channelled water then supplying a head of about 15 feet at bankfull stage.

The planforms of caves, and their passage cross-sections, may be considerably influenced by the selection of planes of weakness during the initial period. Vertical penetration along joints dominated in the Bonnechere Caves, so that each segment of the modern passage is seen to be aligned on a joint fracture. But the horizontal penetration of bedding planes has played some part. The resulting initial form is the "anastomosis"[4]—revealed (when one or other of the enclosing beds falls, or is stripped away) as a dense and very irregular tubular corrosion of the bed surface to a depth of, perhaps, several inches. Some excellent examples are to be seen in the Caves and in the Chute.

Major Development. At the end of the initial phase a complex grid of joint lines had been expanded to form tall passages a few inches in width extending from the present entrance to outlets in the erosional scarp. With this establishment of an unobstructed circulation, the rate of flow of water through the system was greatly increased, although the mean head of pressure had probably fallen a little as a result of further incision in the Chute. Thereafter, the bulk of passage expansion to the present dimensions can be attributed to boring by rapidly moving waters in a "*paraphreatic*" situation, i.e., one of intermittent flooding or not quite complete water fill. That the waters filled most of the system under a small head can be shown by the development of many passages in the grid to accessible size. If a purely gravitational stream had been predominant, then the lowest line in the circulation (A to B—C) because the scarpfoot outlet at C was lower than at E) would alone have been developed. Because it possesses the lower outlet, B—C *has* been expanded to a greater extent than D—E, but not to the exclusion of the smaller system.

Boring is indicated by the shape of passage cross-sections, which approximate circular or oval forms, with irregularities introduced where particularly resistant beds stand out. However, the uppermost passages, especially at D, have not been bored over their total height. The roof parts retain the very narrow joint form of the intitial phase, leading to the supposition of paraphreatic water conditions mentioned above.

Solution appears to have been the predominant agent in this second phase as in the first. The walls are everywhere etched with fine examples of "flutes" or "scalloping"—saucer-like solution pits with a steeper upstream edge which makes them an excellent indicator of the direction of past circulation. Bretz attributes them to corrosion under conditions of turbulent flow.[5] Their directions are shown with straight arrows on the plan; they indicate a fairly simple circulation along the lines indicated, with some return of water from D to the major drainage line. The diameters of a scallop are probably

directly proportional to the velocity of the turbulent currents. In Bonnechere Caves they are relatively large along A—B—C, smaller in D—E, and smallest in the constricted side passages, which seems to confirm this argument. There is little evidence of mechanical erosion in the bores. They are surprisingly free of sand and gravel deposits, indicating an absence of tools.

Decay. At the present time, the same processes of expansion are operating, but much less effectively, and are being overtaken by processes of decay—the collapse of passages at the outlets and elsewhere. Water still circulates through all passages during thaw floods, but does not fill them to the extent that it did in the past. For much of the year, activity is restricted to downcutting by a small stream through A—B—C. When the cap-rock fall to the Second Level in the Chute is cut back above the entrance to the Caves (it is now just a few feet below it), water will probably cease to enter them altogether.

There is no positive evidence of any cavern development downwards from the *Rockland* bench. No *ponors* or *avens* are to be seen. Carbonate deposits are restricted to a few, very small stalactites in the joint roof at D, indicating that little water has been able to penetrate through the calcite sandstones of the *Rockland*.

The Bonnechere Caves are an instructive example of certain principles of the genesis of limestone caverns. Their development shows a simple relationship to controlling factors of structure, lithology, and the local topography. Many characteristics of the solution process are well illustrated and features of a full cycle of erosion from inception to decay may be seen.

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RÉSUMÉ

Les caves de Bonnechère, près d'Eganville, dans le comté de Renfrew, Ontario, sont situées dans une couche paléozoïque, où la rivière Bonnechère a taillé dans le calcaire une étroite gorge coupée de rapides et de chutes.

Bien que de dimensions peu considérables, ce phénomène illustre bien certains procédés de la genèse des cavernes dans le calcaire et les rapports entre maintes phases de la dissolution et les traits structuraux, lithologiques et topographiques.

THE CONTINENTAL SHELF: PHYSICAL vs. LEGAL DEFINITION

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THOUGH DIFFICULT to define in precise language the continental shelf in a physical sense is well known. It consists of a gently sloping submarine platform extending seaward from the continental land masses. In fact, geologists speak of the continental shelf as an integral part of the land areas having elevation above sea level. Structurally, sub-surface material is not basically affected by the existence of the water line of the coast above it. Thus, mineral resources may be found offshore, beneath the surface of the sea-bed, as well as in mountainous terrain or other landforms. The presence of such offshore resources has been a major factor in creating the need for a legally defined continental shelf. In this discussion the physical shelf will be described first as a background for delineating the legal shelf.

The continental shelf slopes seaward to that point where there is a marked steepening of slope to greater depth. In scientific literature one usually sees reference to a depth of either 100 fathoms or 200 metres as being the outer edge of the continental shelf. Maps conveniently show submarine contours of these values to illustrate the outer limits of the shelf. Actually, 100 fathoms equal only about 183 metres, but the location of the break in the slope is so indefinite that it cannot be pinpointed. In fact, the criterion of 100 fathoms tends to be somewhat high since available data show the average depth of the break in slope to lie between the 60- and 80-fathom submarine contours. On the other hand there is definite evidence of continental shelves at much greater depths, the most extreme being 550 metres for the Sahul Shelf off the coast of northern Australia.

The actual angle of slope on a true continent shelf is incredibly small, only about two fathoms per mile, or 0.085 degrees. The human eye cannot detect a slope of even double this inclination. In many instances, however, the surface of the shelf is not smooth, but forms terraces, ridges, hills, depressions, and even canyons. Uneven submarine topography of this type obviously makes the physical shelf difficult to delineate, especially where its outer periphery is fractured.

On the average the continental shelf is about 30 miles wide. But the average is not very meaningful because of the great variation to be found from place to place. Along the west coast of South America, for example, where mountains rise sharply from the coast, the submarine surface in turn plunges to great depths with very little trace of a ledge which could be construed as a continental shelf. At the opposite extreme, the entire Bering Strait area, extending 800 miles north of the north coast of Siberia, is less than 100 fathoms in depth. At other places, also, the width of the shelf is measured in hundreds of miles, including the Atlantic Ocean off the southern coast of Argentina and the South China Sea off the eastern coast of the Malay Peninsula. The Persian Gulf, some 600 miles long by 230 miles wide is nowhere deeper than 50 fathoms. Its seabed qualifies in its entirety as continental shelf.

Because of recent international interest and conflict in Law of the Sea matters the continental shelf gained prominence in international law. The legal profession needed to identify that zone of water along any coast which might be endowed with resources worthy of exploitation. It had become necessary to clarify the rights of sovereign states to exploit offshore resources. Regardless of its location, any given offshore resource must be legally accessible to one sovereign state or another, or be subject to the regime of the high seas and thus accessible to any

sovereign state. Such was the problem faced in the First Law of the Sea Conference held in Geneva in 1958.

Guided by reference to the Report of the International Law Commission of 1956, a legal definition of the continental shelf was promulgated at Geneva in 1958 by the following wording:

> . . . the sea-bed and subsoil of the submarine areas adjacent to the coast but oustide the area of the territorial sea, to a depth of 200 meters or, beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas.

Continuing, the definition went beyond the former Report of the International Law Commission in that it applies to islands as well as continental mainland:

> . . . the sea-bed and subsoil of similar submarine areas adjacent to the coasts of islands.

Supplementary to the definition of the continental shelf, the rights of exploitation were expressly specified:

> The coastal State exercises over the continental shelf sovereign rights for the purpose of exploring it and exploiting its natural resources.

These international texts were passed by a two-thirds majority in the General Plenary session at Geneva, and are now incorporated in Articles 1 and 2 of the *Convention on the Continental Shelf* adopted April 26, 1958.

By analysing the Articles it can readily be seen that a coastal state cannot lay claim to the continental shelf as sovereign territory; rather, the state has sovereign rights for the purpose of exploring and exploiting resources appertaining to the shelf.

In this way, the territorial waters of a state stand in a different legal category than does the continental shelf. Territorial waters, including their sea-bed, are part of the sovereign territory of the state, so that no question arises as to rights to exploit resources within their limits. It is beyond the outer limit of the territorial sea of any state that the definition of the continental shelf becomes critical.

A third dimension also comes into play in recognizing the offshore sovereignty and sovereign rights of a coastal state. Full sovereignty of both water and sea-bed extends seaward to the outer limit of the territorial sea. Beyond this limit the water falls into the regime of the high seas—available to all states—while sovereign rights exist for certain purposes with respect to resources of the sea-bed—available only to the coastal state. Thus, beyond the outer limit of the territorial sea any distant state may navigate freely on the surface of the water, may engage in fishing activities, but may not exploit minerals from the sea-bed of the continental shelf.

Purpose CES has no claim to 200

One rather odd fact about the continental shelf as legally defined is that it has no tangible outer limit. It extends as far seaward as there are resources to develop. If, for example, a mineral substance of commercial value were to be found beneath the ocean floor at a depth of 25,000 feet, and could be exploited, the right to exploit that resource would rightfully belong to the coastal state. That the site of exploitation might be a thousand miles or more offshore would not in the least invalidate the legality of the sovereign right of the coastal state as cited in the Geneva Convention.

Drilling for petroleum serves to illustrate how mineral resources may be exploited many miles offshore from beneath the floor of the continental shelf. Off the coast of Louisiana the placement of oil-well equipment extends to the 100-foot submarine contour, as far as 50 miles from the shoreline. Mobile platforms holding drilling equipment can be taken out to a depth of 200 feet of water. Off the California coast an even more spectacular development has taken place where from a floating platform petroleum can be brought up through 1500 feet of water. The depth of 1500 feet, or 250 fathoms, represents two and one-half times that normally assigned as the maximum depth for the physical continental shelf.

Petroleum from offshore wells becomes increasingly important each year. In addition to large-scale developments off the California and Gulf coasts of the United States, the Persian Gulf also figures prominently. The concessions of major oil companies, when mapped, makes that body of water appear like a checkerboard.

The latest offshore fields to come into production are those in the Gulf of Paria along the Venezuelan coast near Trinidad.

Iron and coal are likewise mined from deposits extending under the sea, as at Jussarö in southwestern Finland, around Sunderland off the eastern coast of northern England, and at Dielette along the Normandy coast of France. The offshore distances involved in these operations quite likely do not exceed the breadth of the territorial seas of the states concerned. Nevertheless, progress in the technical aspects of mining makes it probable that offshore exploitation of solid minerals will advance seaward.

Most fishing activities are associated with the waters of the sea, and not the sea-bed. Consequently, the rights to fish by a coastal state extend only to the outer limit of its territorial sea, or to any other limit so defined legally for this purpose. However, certain species of fish, termed crustacea, do not swim and are constantly in contact with the floor of the ocean. This type, including shrimps, crabs, and lobsters, appertain to the continental shelf rather than the sea above it, as brought out in the 1958 Geneva Convention on the Continental Shelf:

> The natural resources referred to in these articles consist of the mineral and other non-living resources of the sea-bed and subsoil together with living organisms belonging to sedentary species, that is to say, organisms which, at the harvestable stage, either are immobile on or under the sea-bed or are unable to move except in constant physical contact with the sea-bed or the subsoil.

Thus, beyond the outer limit of its territorial sea a coastal state may have exclusive rights to harvest these choice seafoods, but must share the "swimming" fish with other states.

It can be seen how the continental shelf, when legally defined, starts at the outer limits of the territorial sea, which in accordance with U.S. policy means three nautical miles from the low water line along the coast. From this inner line, as stated before, there is no definite seaward limit. But aside from the over-all extent of the shelf outward from the territorial sea there remains the task of identifying it with respect to the several sovereign states of the world. What determines the line between continental shelf areas of two adjacent states? And what determines the division of continental shelf areas of two states lying one opposite to the other across a body of water? In the latter instance the intervening water may be a narrow channel, or it may be a very wide area. Finally, how does the presence of a territorial sea off every coast affect lines of jurisdiction over the continental shelf?

A median line, extending laterally from the coast seaward may serve as the means to divide the continental shelf between two adjacent coastal states. Article 6 of the Convention on the Continental Shelf states this premise in precise language:

> Where the same continental shelf is adjacent to the territories of two adjacent States, the boundary of the continental shelf shall be determined by agreement between them. In the absence of agreement, and unless another boundary line is justified by special circumstances, the boundary shall be determined by application of the principle of equidistance from the nearest points of the baselines from which the breadth of the territorial sea of each State is measured.

An "agreement" as referred to in the Article gives any two adjacent states sufficient latitude to make any arrangement they may wish by which to share resources of the continental shelf. It must be pointed out, however, that such agreements are largely lacking. On the other hand, the median line is based upon geometric principles, and provides a fair and just boundary by which to divide the continental shelf unless other circumstances are present to justify a bilateral treaty with special provisions.

A median line bisecting a body of water between the coasts of opposite states may serve to divide the continental shelf between these states. The wording of the Geneva Convention for this situation is much as that for adjacent states except for reference to the position of the states, that is, opposite one another rather than adjacent. In the Persian Gulf there has been ample opportunity to apply the rule of a median line between opposite coasts. Petroleum concessions of, say, Saudi Arabia may go half way across the Gulf toward Iran. Thus, on opposite coasts,

Saudi Arabia and Iran divide the resources of the sea-bed by a geometrical line, every point of which is equidistant from the nearest point on the Saudi Arabian and Iranian baselines from which the territorial sea is measured.

Median line boundaries across waters of the continental shelf are actually a continuation of those used to divide the territorial seas among sovereign states. For example, a median line extending seaward from the coast may be used to separate the territorial seas of two adjacent coastal states. Continuing beyond the outer limit of the territorial sea the same line then becomes a boundary for distinguishable sovereign rights with respect to the continental shelf. Between opposite coasts the same principle applies in instances where the water distance between the states coincides with the sum of the distance of the breadths of the territorial seas of the two states.

The pattern of median lines just described represents those which might be found along coasts relatively simple in configuration. In cases of coastal indentations and offshore islands, or in archipelagos, the pattern may become quite complicated. Also, where interests of three or more states come into contact within a small area, median lines may form what at first glance appears to be an intricate and meaningless design! Nevertheless, the median line principle, regardless of the complexity of physical and political data from which it is plotted, can be applied in determining the sovereignty and sovereign rights in a precise manner unaffected by subjective reasoning

In conclusion, it has been shown how the legal interpretation of the continental shelf was applied to a physical situation. That the two versions cannot possibly coincide is easy to see. In fact, the continental shelf as legally defined is not, strictly speaking, a continental shelf at all, and might well go by another name. It is an offshore area related to existing resources of the sea-bed and the sovereign rights governing exploitation of these resources. In this respect the legal shelf serves a definite purpose, and has been successfully conceived in so far as the states of the world can share in the exploitation of offshore resources with maximum benefit and without international friction.

RÉSUMÉ

Bien que difficile à définir précisément, la plate-forme continentale, au sens physique du terme, est bien connue. Dans cet article, l'auteur présente une description des traits physiques de cette zone et suggère que ces derniers servent de critères dans l'examen des limites de la plate-forme, telles que définies légalement à la première Conférence sur les Droits Maritimes, tenue à Genève en 1958.

Il s'attache à démontrer l'incohérence de l'interprétation légale et du caractère physique de la plate-forme continentale.

En fait, cette plate-forme, telle que décrite en termes légaux, n'est pas du tout, à proprement parler, ce qu'elle prétend être et pourrait tout aussi bien avoir un autre nom. C'est un espace, au large des côtes, auquel sont liées les ressources existantes des fonds marins et le droit des états à l'exploitation exclusive de ces ressources. Vue sous cet angle, la définition légale de cet espace sert donc à un but précis et on peut dire qu'elle a été conçue avec succès puisque, grâce à cette formule, les ressources de la mer par-delà cette zone territoriale peuvent être exploitées avec le maximum de profit et sans conflits internationaux.

Review Article

GEOMORPHOLOGY AND THE GEOGRAPHY STUDENT

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DURY, G. H.: *The Face of the Earth*, Pelican Books A447, Penguin Books Ltd., 1959, 223 pp.

SPARKS, B. W.: *Geomorphology*, Longmans, Green & Co., London, 1960, 371 pp.

STRAHLER, A. N.: *Physical Geography* (2nd edition), John Wiley & Sons, Inc., New York, 1960, 534 pp.

WOOLRIDGE, S. W. and MORGAN, R. S.: *An Outline of Geomorphology: The Physical Basis of Geography* (2nd edition), Longmans, Green & Co., London, 1959, 409 pp.

FOR HUMAN BEINGS who inhabit the "Face of the Earth" and have already published a map of the physiographic divisions of the moon on a scale of 1:3,800,000, the dearth of comprehensive, up-to-date works on terrestrial landforms seems rather surprising. Although none of the four books under review was written to fill the void, it is most encouraging—one might add, refreshing—to be able to discuss the publication of two new books and the revision of two standard textbooks, each of which has been influential in interesting students in geomorphologic studies on its own side of the Atlantic Ocean. The preceding sentiments, and many to follow, are very similar to those which have recently been expressed by F. K. Hare in a review article on "Climatology and the Geography Student" in the CANADIAN GEOGRAPHER (no. 16, July, 1960, p. 36). This is because climatology and geomorphology, the foundation stones of physical geography, have undergone a somewhat parallel growth, although climatology has made the more rapid strides in recent years.

The widespread acceptance and precise use of geomorphology as a technical term for "the study of the evolution of landforms, especially landforms produced by the processes of erosion" (Sparks, p. 1) does not date back much beyond twenty-five years. Indeed, the first edition (1937) of *The Physical Basis of Geography: An Outline of Geomorphology* by Wooldridge and Morgan was one of the earliest books to use the term in a title. The reversal of the main and sub-titles in the second edition (1959) is symptomatic of the change in terminology and the recognition of geomorphology as a field of specialization. "Geomorphology" is employed in a more restricted sense than the broader term of physiography. Some writers continue to include geomorphology under physiography. Or, for the sake of title brevity, they include it in the appropriate section of introductory texts to physical geography, as in the book by Strahler, or in physical geology.

All four books can be read, or studied, by the average first-year college student who has had no previous training in geomorphology, although some background is desirable for the perusal of the books by Sparks and Wooldridge and Morgan. The writing styles and general approaches of the books seem to reflect the differences, whether real or imagined, which some people attribute to the respective educational systems of Great Britain and Anglo-America. In this reviewer's opinion, the three books published in Great Britain are written from a more mature viewpoint (in the sense that they stress unsolved problems and differences in theories) than similar North American books, of which Strahler's may be cited as a typical example. This does not imply, of course, that Strahler is unaware of differences in theories. He is most active in research, and enjoys an enviable reputation as a geomorphologist with original ideas. It does suggest, however, that introductions

to geomorphology in North America tend to be cut-and-dried on controversial problems. To illustrate the approach of the three British books: Dury (inside front cover) "examines some of the hotly-disputed problems which have to be solved"; Sparks (p. v) stresses "the deficiencies of theories"; Wooldridge and Morgan (p. v) are careful "to indicate such wavering of opinion" on controversial subjects.

On the debit side, the cartographic standard of the British books is truly deplorable. Even experienced geomorphologists would have difficulty interpreting many of the drawings, if they had not access to text and captions. Few geomorphologists are as facile with a pen as C. A. Cotton, W. M. Davis, or A. K. Lobeck, it is true, but publishers too often allow an author's poor drawings, or those of students or of not too artistic friends, to appear in otherwise technically good books.

Although the authors reviewed here tend to agree in their concept of the field of geomorphology, they differ markedly in their approaches to geomorphological problems and research. Whether explicitly stated in the books under review or in other published writings, these differences are echoed in the tenor of the books. The authors are unanimous in their appreciation of the necessity for detailed field work and the analysis of topographic maps. There is less unanimity of opinion on the desirability of intensive laboratory investigations. Strong divergent views centre on "quantification" in geomorphology. Wooldridge and Morgan express themselves in unequivocal language: "There has been a recent attempt in certain quarters to devise a 'new' quasi-mathematical geomorphology. At its worst this is hardly more than a ponderous sort of cant. . . . If any 'best' is to result from the movement, we have yet to see it. . . ." (Preface to second edition.) These opinions, coming as they do primarily from Wooldridge, a doyen among British geomorphologists, must carry considerable weight and will undoubtedly influence the thinking of many readers. Sparks is less definite but points out that the "student of process often finds a greater need of mathematical and physical knowledge, especially when he is concerned with the movement of different types of material, whether by water, ice or wind" (p. 5). Dury is in favour of the "quantitative" approach, for he states: "geomorphology is passing from the descriptive into the analytical phase, and developing a theory of its own—not without rumbling objections from some of its devotees" (p. 2). Strahler is most emphatic when he writes: "without penetration into mechanics, thermodynamics, and higher mathematics, the degree of explanation that can be achieved by verbal description must necessarily be limited . . . in the treatment of geomorphic processes and forms . . ." (Preface, p. vi). These fundamental differences in opinion of the authors should be borne in mind by readers who wish to follow the currents of geomorphic thought.

The Face of the Earth by Dury may be highly recommended for the non-specialist who wishes to obtain a reasonably accurate, yet readable, survey of geomorphology. It may serve equally well for a person who wishes to have a quick refresher on geomorphology or to have his general knowledge brought up to date. The book is free from unnecessary technical jargon. Dury writes with catching enthusiasm for his subject, although one might wish that his diagrams and sketches were as clear as his words. The treatment of geomorphic principles and problems is balanced, and similar to that of most introductory books on geomorphology. Although the book bears the stamp of its British origin, neither areal nor topical coverage is parochial. Examples have been drawn from all continents. Of interest to Canadian readers is the chapter on "Frozen Ground." Unfortunately, this chapter is probably the poorest in the book. Even making allowances for space limitations, there are many misleading or inaccurate statements, for example, in descriptions of the nature of permafrost and the active layer, frost-soils ("patterned ground"), ground-ice, and the oriented lakes of the Arctic Coastal Plain of Alaska (with the startling generalization that they are a "final illustration of the distinctive nature of the permafrost belt"). However, Dury should be congratulated for his initiative in including a

chapter on "Frozen Ground," as it is customarily a neglected topic.

Sparks, the author of *Geomorphology*, is a Lecturer in Geography in the University of Cambridge. His book is aimed at students who have a prior knowledge of geomorphology, but it delves into general principles in sufficient detail to be used as a beginning text in geomorphology at Canadian universities. The approach of the book is systematic in nature; its content shows considerable familiarity with current literature, the development of new theories, and the replacement or discarding of old ones. Each chapter ends with carefully chosen references of some twenty to thirty items, on many of which the author has made helpful comments. The photographs in the book have been selected with a discriminating geomorphic eye, and their reproduction is good. Many of the diagrams are difficult to interpret, although they may be technically accurate.

After an introductory chapter on the aims and position of geomorphology, the book commences, in chapter 2, with "The Davisian Geographical Cycle," which is intended as a framework within which a discussion of geomorphic processes can take place. To this reviewer, it seems unwise to plunge the student into the Davisian cycle before he has a good grasp of geomorphic principles. In addition, the Davisian cycle is a debatable and phantom "ideal"—somewhat like the planetary wind diagram—which the student discovers may not really exist, after he has learned all about it. If any chapters are to be singled out for especial comment, perhaps chapters 4 and 5 on "The Development of Slopes" and "The Nature of a River Valley" are most deserving. In these two chapters Sparks has done a creditable job of discussing the difficult and controversial aspects of slope development. The last chapter treats of "Erosion Surfaces and their Interpretation." This is a subject which was much more in vogue in North America twenty or thirty years ago than it is now. Consequently, the North American reader may find much to interest him in the difficult, yet fascinating, problem of the reconstruction of old erosion surfaces.

An Outline of Geomorphology by Wooldridge and Morgan is the second edition, with a title change from *The Physical Basis of Geography*, a book which has served as textbook and guide to a generation of geographers. Its influence has permeated teaching, geomorphic thought, and field studies. There is not a great change in style, content, or emphasis between the two editions. Rather, the second edition is basically the first brought up to date. The subject matter differs considerably in presentation from most books on geomorphology, particularly in the attention given in the first third of the book to the origin of the earth, the earth's interior, isostasy, the nature and origin of the earth's major relief, earth movements, mountain-building, and tension in the crust of the earth. The major portion of the book is devoted to landforms due to erosion, a classical approach being used. The writers are not carried away by new theories—in fact, there is a tendency towards conservatism—but they attempt to discuss both sides of a controversial point. In this respect, the book makes salutary reading for the young geomorphologist who may feel that there are few pathways left to explore. In contrast to many writers, the authors have not attempted to make their book encyclopaedic; it reads more like prose than most textbooks. The bibliography of the 1959 edition is essentially that of the 1937 edition, with relatively few added references. The tremendous literature on geomorphic topics, published in the last twenty years, is largely ignored. Likewise, there has been little change in the illustrations.

Strahler's *Physical Geography* is the most "textbookish" of the four works. Only the latter half of the book deals with geomorphology, but much material of geomorphic interest may be found in the first half, which treats of the earth as a globe, weather elements, climate, and soil. *Physical Geography* literally breathes author-publisher symbiosis. The writing is clear, the line drawings of exceptionally high calibre, the page designs excellent, and that standard of editing of the best. However, the half-tone illustrations, while satisfactory, have suffered in reproduction and lack tonal contrast.

The second edition of *Physical Geog-*

raphy shows a rearrangement of the sequence of the main sections and the addition of new material, particularly on ground water, run-off, stream channel characteristics, and landforms made by winds. Each chapter ends, as before, with review questions and a set of topographic exercises, of which some are new. Four full-page topographic sheets (at a scale of 1:62,500) with brown contours and blue hydrography are printed on the inside cover and flyleaf pages. The bibliography, which exceeds five hundred references, may be particularly recommended as it includes both classical and recent ones.

One criticism is that each new term is printed in italics; thus the reader may become overwhelmed by the number of words so introduced. For example, in one column (p. 379) the following are italicized: drainage density, low drainage density, coarse texture, medium drainage density, medium texture, high drainage density, fine texture. Perhaps this helps the student, but confusion may also result. How accurately can a student separate important terms from less important ones, and those which have a recognized standard usage from those which have not?

The publication of the four books points out trends and needs in geomorphology books and student requirements. In trend, there is a change from emphasis on the Davisian concept of *stage* towards that of *process*, a welcome and progressive step. The books also demonstrate that there is still a need for an advanced textbook, suitable for a senior course in geomorphology. The deficiencies apparent in geomorphology books are part and parcel of the rapid scientific advances taking place in fields bordering geomorphology, for example, hydrology and soil mechanics. A greater incorporation of research from these fields is required in current geomorphological literature, whether in a discussion of meanders, glacier flow, or landslides. This may always be the case with an earth science, because the subject of study is common to many disciplines, each with its own distinctive contribution to make.

In the above-mentioned review of climatology Professor Hare closed his discussion with a strongly worded paragraph stressing that "a knowledge of mathematics and elementary physics does more than open the door to climatology; it is almost equally important in the study of geomorphology. . . ." This reviewer would be remiss if he did not add his wholehearted support to the opinions expressed by Professor Hare. Perhaps a student, upon perusing current geomorphology books, may question the need for such knowledge. If so, it does not alter the argument but only serves to demonstrate that it is difficult for books to keep pace with research. It is hoped that the books under review will contribute to the geomorphological knowledge of many, and that of these, some will be stimulated into active geomorphic research. If so, it is certain that all of the authors will be satisfied with their contribution towards the richly varied and interesting study of geomorphology.

Geographica

PERMAFROST IN SOUTHERN LABRADOR-UNGAVA

A NEW MAP of permafrost in Canada has been published recently based on actual observations, rather than on theoretical grounds (Brown, 1960). In Labrador-Ungava the approximate southern limit of discontinuous permafrost passes through Schefferville and along the 55th parallel. As the southern boundary is drawn from site reports of permafrost, the accuracy of the map is proportional to engineering and mining activities in the area.

In 1960, engineering projects connected with the Wabush Lake iron deposits, the Twin Falls power site and transmission line, and the building of the Northern Lands Company Railway from mile 227 on the Quebec North Shore and Labrador Railway have revealed scattered permafrost 140 miles to the south of Schefferville and the southern limit of discontinuous permafrost proposed by Brown.

The writer visited Twin Falls on Unknown River in December 1960. The falls are 108 miles east-southeast from mile 287 on the Q.N.S. & L. Railway and are being developed to supply power to the Wabush Lake area. Excavations on the floor of Bonnell Canyon, a tributary of the Unknown River, showed frozen ground at 360 m. (1190 ft.) above sea-level. The Bonnell Canyon is a steep-sided, narrow valley trending north-south along a fault and it has a maximum relief of 100 m. (300 ft.). The frozen ground was discovered by engineers in early November, and its vertical extent suggests that it was not due to seasonal frost penetration, but must be considered permafrost. The original vegetation of the valley floor was swamp and alder, with organic material forming a surface layer .6 m.–1.2 m. thick. On the west side of the canyon, 4.5 m. of glacial till was removed before frozen ground was first encountered. The vertical and horizontal extent of this permafrost body is unknown, but during excavation it was observed that the permafrost thickened both to the south and to the west, and at the limits of the present pit it had a vertical thickness of 8 m. At this site the permafrost was identified by the development of ice lenses and wedges in bedded, varve-like deposits of silt and sand. In one 2-m. exposure eight horizontal ice bands were noted, varying in thickness from 1 cm. to 5 cm.

On the east side of the exposure, two further bodies of permafrost were identified by the development of ice lenses, 5 cm.–20 cm. thick. The two bodies widened upwards from their base 3 m. below the surface, and appeared to be separated by a peat basin which lensed out above the permafrost. This situation is contrary to the normal pattern of development, where bog and muskeg are associated with the occurrence of permafrost. Analysis of several samples showed that the fine sands and silts within the permafrost body contained 30–35% water by weight. To the north and the south the sediments become coarser. They are favourable for ice-lens development and it is difficult to decide visually whether permafrost exists. However, reports on the nature of the coarser sediments during the excavation suggested that the permafrost extended to the south for a total horizontal distance of 30 m. (A. Graves, personal communication). It is anticipated that further work will continue locally down to the bedrock, 7 m. below the present floor of the pit, and will provide more information on the vertical extent of the permafrost. The existence of permafrost at such a low elevation probably results from the peculiar topographical conditions. The steep walls and orientation of the canyon keep the floor in continual shade, so that the annual average temperature on the canyon floor will be much lower than other areas at that elevation and latitude in Labrador-Ungava.

Engineering activities connected with the building of the Northern Lands Company Railway have resulted in reports of permafrost in the Wabush Lake area. Frozen

ground was observed in 1959 during the construction of the railway (Pryer, personal communication) four miles west of mile 227. From mid-July to late September, ice lenses and ice masses, occasionally as much as 30 cm. in thickness, were excavated at 1–2 m. below the surface. The site lies at an elevation of 535 m. (1750 ft.) in a shallow cut (maximum depth 3 m.) and 500 m. in length. Frozen ground was reported to be virtually continuous for the whole length of the cut; it occurred under a surface layer of 60 cm. organic material, and was located principally in fine sands and silt with some coarser material. Both the extent of the frozen ground and its presence in the late summer months suggest that it is permafrost.

During the construction of the transmission line from Twin Falls to Wabush Lake, frozen ground that is considered permafrost was encountered 20 miles west-southwest from mile 227 at an elevation of 545 m. (1790 ft.). The permafrost body was located on a small knoll rising out of muskeg. Excavations in early November continued down to 5.5 m. below the surface but failed to locate the base of the permafrost which probably extended beneath the muskeg. The reports state that ice lenses were frequent in silts and fine sands which had 34% water by weight in their frozen state. Temperature measurements taken in the ice lenses after being exposed, and with the air temperature above 0°C., gave a temperature of —1.8°C.

During the construction of the Q.N.S. & L. Railway, permafrost was reported from mile 245 and 253 at 515 m. (1694 ft.) and 505 m. (1662 ft.) respectively (Woods, Pryer, Eden, 1959). At the cut at mile 245, 2.0 m. of material was removed below the subgrade, and it is suggested that all the permafrost was not removed even then, since to date 1 m. of additional ballast has been required to compensate for annual subsidence. Within the limits of the shallow cuts, the permafrost had a horizontal extent of 32 m. at mile 245, and 16 m. at mile 253.

Exploratory drill holes have struck permafrost in the Wabush Lake iron ore bodies, though as yet no detailed report has been received.

These various reports suggest that the southern boundary of discontinuous permafrost in Labrador-Ungava must be drawn at least 140 miles south of Schefferville. All reported occurrences so far are of permafrost in frost-susceptible materials such as silts and fine sands, and it is generally found under a surface layer of organic material. In tracing the southern limit of permafrost within the peninsula it should be noted that the elevations at which permafrost has been reported (discounting the Bonnell Canyon location as a special case) have averaged about 520 m. (1700 ft.) above sea level. There is thus a decided possibility that scattered bodies of permafrost exist some 300 miles south of Schefferville where the Laurentian scarp rises to 1000 m. (3000 ft.) and over.

The writer wishes to acknowledge the help and assistance in the preparation of this report from: A. Graves of the Shawinigan Engineering Company, R. W. J. Pryer of the Q.N.S. & L. Railway, and B. Crowley of the Shawinigan Engineering Company, and from the British Newfoundland Corporation and Shawinigan Engineering Company for providing the opportunity to visit the Twin Falls Power project. Travelling expenses were provided from a National Research Council grant made to Professor J. B. Bird, McGill University.

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[J. T. Andrews]

THE PERIGLACIAL BULLETIN (BUILETYN PERYGLACJALNY)

THE APPEARANCE in 1954 of the *Periglacial Bulletin* was an important event. It launched a new bulletin devoted exclusively to periglacial geomorphology, a subscience which in the ensuing years showed a remarkable development. It was fitting that this specialized bulletin should appear in Poland, where, as early as 1909, the term "periglacial" and the concept of a "periglacial environment" were first introduced by Walery Lozinski. However, for many years in Poland the periglacial concept failed to arouse much attention, and it is only recently that Lozinski's idea has gained full understanding, and become the subject of systematic study. The names of Dylik, Jahn, Klatka, Halicki, and others are among the pioneers in the study of periglacial geomorphology, and certainly it has been their enthusiasm more than anything else which has fathered this new and vital publication.

In other areas of the world the study of periglacial geomorphology is even more recent. Canada, for example, has not given serious consideration to periglacial problems until within the last decade, and at that little has been achieved to date.

Research in periglacial geomorphology everywhere in the world has proceeded along independent lines, with little cross-fertilization of ideas or exchange of data. A complicated and confused nomenclature has grown up over the years, and has created a problem of communication which still remains. The editors of the *Periglacial Bulletin*, realizing these problems, no doubt created the publication to meet the needs of this rapidly growing science. To quote the editor's introduction to the first volume:

> . . . Its chief purpose is to provide articles of a surveying character where new lines of inquiry, the method and present stage of development of periglacial thought should be presented and discussed.

In addition the problem of nomenclature was also in their mind:

> . . . Owing to the rapid development of periglacial research a whole number of particular terms came into being. Materials concerning nomenclature are meant to facilitate the comprehension of the terms derived from many different languages. In future, they might prove helpful in the task of introducing some order into terminology.

Furthermore, it was stated that in format the *Periglacial Bulletin* was to include the following sections: articles, contributions to periglacial nomenclature, scientific notes, critical reviews, and bibliographies. It has developed broadly along these lines, although no firm format has evolved, each volume tending to constitute a complete unit in itself. It was not intended that the bulletin should become a periodical, but rather be issued when sufficient material of interest was collected. Apart from 1956, when two volumes appeared, only one volume was published for the years 1954 to 1958 inclusive. No volume appeared in 1959, but, on the other hand, four volumes appeared in 1960, perhaps demonstrating the very rapid recent growth in the field. Some volumes have been reserved for reports of meetings of the Commission on Periglacial Geomorphology of the I.G.U. Volume 4, for example, gives reports presented at Rio de Janeiro in 1956, volume 8 the Periglacial Symposium held in Poland in 1958, volume 9 of the Pre-Würm Periglacial Colloquium held in Liège in 1959, and volume 10 the Periglacial Symposium held in Morocco in 1959.

The publication has been multilingual, being divided, usually, into three sections: one Polish, one Russian, and third published in other modern European languages (English, French, German, or Italian). Some volumes have included all three sections, as for example, volumes 2, 3, 5, 6, 7, and 8. Volumes 4, 9, and 10 appeared in one section with untranslated articles in English, French, and German. On the other hand, volume 1 appeared in two sections, the first in Polish and the other in Western European languages. It is usual for articles in Polish (when included) to contain bibliographies, figures, and plates; articles appearing in other languages contain the text only.

It is not proposed to analyse the contents of the *Periglacial Bulletin* here. However, note should be taken of several significant contributions. In the field of nomenclature six important papers have been published, which add greatly to the understanding of European terms (especially Russian). Survey articles on periglacial phenomena and the status of research within the country have been published for Canada, Japan, Svalbard and Lappland, Sweden, Poland, Netherlands, Belgium, British Isles, France, Albania, Australia, Morocco, Czechoslovakia, Italia, and Rumania.

In geographical distribution seventy-two per cent of the 145 items listed and appearing in the first ten volumes are on European topics. Poland dominates the field with fifty-one contributions, or thirty-five percent of the total. North African topics account for seven references or approximately five per cent of the total, undoubtedly due to the leadership of Raynal of Morocco, Chairman of the Commission on Periglacial Geomorphology of the I.G.U. North America has contributed only four items, which underlines the fact that on this continent the study of periglacial geomorphology lags far behind recent advances made in Europe.

In content, the *Periglacial Bulletin* has reflected the interests of European, and more especially Polish, geomorphologists in "fossil" phenomena such as ice wedges, loess, strata deformation structures (such as involutions), and the products of cryoturbation and congelifraction. This is no doubt due to the fact that few or no active processes or phenomena exist in these countries today. As little work has been attempted in North America in this phase of periglacial geomorphology, and as there is little reference to it in standard texts, the *Periglacial Bulletin* should prove invaluable in studying techniques and problems involved.

In addition, the *Periglacial Bulletin* contains much valuable material on practically every phase of periglacial study including philosophy, mapping, bibliographical material, book reviews, and instrumentation. Every geographer interested in geomorphology, no matter how slightly, should acquaint himself with this important publication.

[Frank A. Cook]

OBITUARY

The death of Herbert O. Frind in April 1961 has deprived the Canadian Association of Geographers of one of its most enthusiastic sustainers. He was both a charter and a life member of the Association. Amongst his other lively interests, especially mountain climbing and alpine research, as well as conservation, Mr. Frind was a widely travelled and keen amateur geographer. His numerous schemes and ideas on the promotion of geography in the fields of teaching and research will be sadly missed by the many members of the Association who knew him well.

[W. G. Dean]

REVIEWS

The Geological Evolution of North America, by T. H. Clark and C. W. Stearn, The Ronald Press Co., New York, 1960, 434 pp.

The production of geography textbooks in Canada presents many problems for both authors and publishing companies. In the last decade it has been possible to prepare special textbooks for a large potential market such as the high schools; in the universities where the number of students is inevitably less, the problem is still far from solved. Although it might be expected

that all university textbooks in systematic geography would be global in approach, even a brief examination of English-language texts from both sides of the Atlantic shows that this is rarely so. Introductory texts in both physical and human geography for the large first- and second-year geography classes in Canadian universities are, with few exceptions, published in the United States; they are biased in favour of examples from the United States where this is possible. Even in regional geography, the departmental programme may require the lecturer to suggest a single text for North America, in which case it will almost certainly be American, for there are no suitable textbooks by Canadian scholars.

One solution to the problem, when the numbers of Canadian students do not warrant the publication of non-specialized texts for Canadian universities, is to publish books that are also acceptable in foreign universities.

The Geological Evolution of North America is an example of this approach; written by two geologists from McGill University and published in the United States, it provides a comprehensive regional treatment of the historical geology of North America. After an introductory section in which the scope of historical geology and the geosynclinal theory are examined, the continent is divided into four main regions: the stable interior; the two main geosynclinal areas, the Appalachians (and the related Ouachita systems) and the Western Cordillera; and the Canadian Shield. Each of the major divisions is examined as far as is practicable in terms of its structural and sedimentary evolution. The authors break the tradition of including the evolution of life in the chapters on geological development, and place this material in a separate fifth part; together with the appendices that examine the plant and animal kingdoms—in geological terms—this section presents an excellent introduction to the topic.

The geography undergraduate who intends to specialize in geomorphology should acquire in his early years at university the knowledge presented in this book in addition the necessary physical geology that is required to understand it. To the geographical profession as a whole the most interesting parts will probably be the short sections on the Canadian Arctic, the Canadian Shield, and the Great Ice Age. The first two are particularly valuable as they summarize the latest hypotheses on the evolution of the areas, presenting information that is available in no other textbook. The section on the Great Ice Age lays emphasis on the application of stratigraphic evidence to the history of the glaciations. It is perhaps a less successful section than the other two, largely because recent additions to our knowledge of the Pleistocene period are so great that it is virtually impossible to provide an integrated picture of the events for the student for whom the book is intended.

The Geological Evolution of North America is successful because of the basic plan followed by the authors and because of the clear and simple language which they use. It is illustrated by many effective maps and diagrams. It was unfortunate that, on the location map of the Arctic Islands, the islands named after the brothers Ringnes were incorrectly spelled, but this is a minor error in an exceptionally interesting book.

[J. B. BIRD]

Indian Life in the Upper Great Lakes, by G. I. QUIMBY, University of Chicago Press [University of Toronto Press], 1960. 208 pp., 75 maps and illustr.

IN THIS, his latest, Quimby traces and defines the sequence of cultures that has occupied the upper Great Lakes region from 11,000 B.C. to 1800 A.D. This in itself is a very large project for a slender volume of only 182 pp.; but, in addition, the author undertakes to present this vast quantity of data in a form which will be meaningful to the interested layman.

His method, generally, is to relate his cultural sequences to an environment that is gradually but constantly changing. To do this, he delves into such diverse fields as Pleistocene geology, climatology, pollen analysis, radio-carbon dating, and ecology. These are formidable topics in themselves, yet Quimby not only simplifies them for the general reader, but weaves them together to form a rich dynamic whole.

Apart from methodological considerations and geological background, the story

really begins with the Port Huron glacial retreat some 11,000 years B.C. By studying the distribution of fluted points and mastodon remains, Quimby demonstrates that they occur together, and only below the terminal moraines of the Port Huron advance. That is, the earliest people in the Upper Great Lakes region were hunters who lived on the Pleistocene mammals which occupied the cool, wet country at the foot of the glacier. Slowly, as the glacier retreated, these mammals—particularly the mastodon—either became extinct or retreated northward in reduced numbers.

As the climate changed, vegetation changed, and with it the fauna on which man was dependent for sustenance. What happened to our original immigrants, the mastodon hunters, is not known. Possibly they moved northward, following the mammals and the climate to which they were accustomed. More likely, they blended with the Aqua-Plano culture which succeeded them, occupying the area from about 7,000 to 4,500 B.C.

In due course, this group also disappeared. Possibly they too followed the retreating vegetation zones northward, to be replaced in turn by the Boreal Archaic and the Old Copper Cultures some 5,000 years B.C. The latter is a fascinating culture, the first in the new world (and perhaps the entire world) to use metals. This culture appears to have been an indigenous development with a technology designed to utilize the numerous deposits of almost pure copper which occur in the Lake Superior drainage basin.

The "modern" period begins some 2,500 years ago with the introduction of pottery and burial mounds, followed shortly by the introduction of agriculture. It is this combination of pottery and agriculture which characterized the cultures found in the area by the first Europeans. Again, however, this was not a mechanical process of adopting new ideas and inventions as they were developed or introduced to the region. For the ability of a group to grow corn, beans, squash, or tobacco is sharply restricted by an unfavourable environment. We find, then, that agriculture is more important in the southern portions of the area, while hunting, fishing, and gathering still predominate in the northern portions.

This constant attention to environmental background is one of the outstanding contributions of the book. The author shows repeatedly the intimate ties that link man with his environment, particularly in earlier hunting and gathering periods.

There are a few sins of omission, but these are probably not too important, at least for the general reader. More serious is the author's tendency to deal with the later periods in a rather mechanical manner, and to accept at face value some reports that should have been read more critically. The general reader would assume that the Effigy Mound Culture of Wisconsin and the Lalonde Culture of Ontario were comparable entities. According to any known meaning of the word "culture," this is not so. Lalonde is at least a pottery type, and at most, a stage in Iroquois development in Ontario.

[W. A. KENYON]

Allgemeine Geomorphologie, by DR. HERBERT LOUIS, o. Professor der Geographie an der Universität München. Walter de Gruyter & Co., Berlin W. 35, 1960. xviii + 354 Seiten, mit 100 Textfiguren, 98 Bildern, 2 Karten. DM 36. 9½ × 6¾ inches.

THIS IS volume I of a new series entitled *Lehrbuch der Allgemeinen Geographie*, edited by Professor Erich Obst. It is to be followed by volumes on climatology, hydrography, geography of vegetation, social and population geography, settlement geography, and economic geography to complete an imposing and comprehensive treatment of geographical science.

The volume by Prof. Louis is divided into three parts: (*a*) a very short historical introduction; (*b*) a brief discussion of the gross morphological features of the earth's surface, with reference to continents and oceans, the theory of isostacy, crustal movement, and continental drift; (*c*) discussions on the detailed organization of surface formations. The third section occupies most of the book, taking up such topics as weathering, river erosion, karst relief, glaciation, deserts, coastal forms, the sea floor, volcanism, and the geomorphological activities of mankind.

Almost forty pages are devoted to bibliography. While, naturally, most of the titles are in German, other languages, and

especially English, are not neglected. The works of Bowman, Cornish, Cotton, Daly, Dana, Davis, Flint, D. W. Johnson, Lewis, Shepard, Steers, Tyrrell, Veatch, and Williams are cited a number of times. This is in contrast with books in the English language such as that of Strahler, whose long and carefully compiled bibliography is almost exclusively composed of American contributions, or that of Monkhouse, whose much briefer lists include mainly British publications. One therefore cannot resist a feeling that the German student will emerge from his undergraduate studies in physical geography with a broader understanding of landforms than either his American or his British counterparts.

The volume is illustrated with well-drawn diagrams, many of which have subtended rather long explanations which are very useful. Special mention must also be given to *Bilderteil*, a separate pamphlet in the pocket inside the back cover, in which the photographs are displayed along with clear and interesting comments.

In this first volume of the series Professor Louis sets a high standard which allows one to look forward with some anticipation to the appearance of the succeeding volumes of *Lehrbuch der Allgemeinen Geographie*.

[D. F. PUTNAM]

Lexicon of Paleozoic Names in Southwestern Ontario, by C. G. WINDER: University of Toronto Press, Toronto, 1961. 121 pp., $6.00.

"THE PURPOSE of this lexicon is to summarize the definition of all names which have been used in describing the Paleozoic stratigraphy of Ontario including the accepted, the controversial, and the invalid terms" (Preface, p. v). Clearly the confusion and misunderstanding attached to the known formations, groups, members, and beds of Paleozoic rock in southern Ontario have long required clarification for both "specialist" and layman alike. Dr. Winder, in a comparatively simple and succinct fashion, outlines the origins of the names of these various rock units, gives either the *type locality* if the name was first mentioned in Ontario, or the *reference locality* in Ontario if it is of foreign origin, and summarizes the history of the authoritative opinions concerning the proper definition and usage of the name. He also includes a brief lithologic description of each unit, its relation to other units, and cites the definitive references for the 134 units he describes.

This reviewer is not competent to judge the value of the book to specialists, but for the non-specialist it at least compiles and sorts out some of the confusion surrounding Paleozoic nomenclature. For geographers and geomorphologists working in southern Ontario it is a useful research tool, not only for its concordance of descriptions, but also as a compact source of reference material.

[W. G. DEAN]

ABSTRACTS

ABSTRACTS OF PAPERS PRESENTED AT THE 11TH ANNUAL MEETING OF THE CANADIAN ASSOCIATION OF GEOGRAPHERS, McGILL UNIVERSITY, MONTREAL, 1–4 JUNE, 1961

J. T. ANDREWS: "VALLONS DE GELIVATION" IN CENTRAL LABRADOR: A REAPPRAISAL

Twidale has described[1] a system of valleys with an alcove-like morphology, situated on the western scarp of Dolly Ridge, three miles east of Schefferville in Central Labrador. He suggested that these valleys were the result of the widening of structural lines of weakness by the repeated freezing and thawing of water in joints and crevices, the frost-riven material being removed by solifluction. These valleys were called "vallons de gélivation." They were re-examined during the spring and early summer of 1960. Detailed measurements were taken on the range of temperature fluctuations at the rock/snow

interface to test the hypothesis, and the entire system of valleys was mapped by a plane table so that a comparison of their morphology would be facilitated.

It is concluded that the previous description of the valleys can only be accurately applied to four out of twelve associated forms. The remainder of the valleys are breached through the escarpment crest, and become progressively unrelated to structure towards the north, the last valley actually possessing a marked sinuous form. The valleys are essentially the product of sub-glacial meltwater activity during the final stages of the deglacierization of the Schefferville area. Similar forms from this area are described in support of this thesis. Apart from the morphological criticism of the previous hypothesis, it is also concluded that the suggested mechanism for the formation of the valleys is unsound, and that the role of mechanical weathering in Central Labrador has been overestimated.

[1]Vallons de gélivation dans le centre du Labrador, Rev. de Géomorph. Dynamique, 7 (1–2), 1956, pp. 18–24; Vallon de gélivation dans le centre du Labrador, *ibid.*, 9 (5–6), 1958, pp. 84.

Arne Bjerre: spacial dynamics of modern milk sheds. the toronto milk shed: a case study

In this preliminary study an attempt is made to define and clarify the characteristics and principles underlying dynamic changes in the location of the most intensive branch of dairy land use—that of fluid milk production. This land use activity is relocating and shifting within an area serving a central city in rapid growth, in this case Metropolitan Toronto.

The study and its theory is based on reliable dairy statistics. It reveals characteristic changes in areas of location of milk producers, as well as in the number of producers shipping to the city market. Thus far, the study seems to indicate the existence of certain laws governing the pattern of location of this activity as well as its changing pattern in the landscape. According to geographical character, and possible potential usefulness, these laws may be of general interest to geographers studying land use and other phases of economic geography. They may become of value for an improved understanding of the spacial dynamics of an economic activity or land use within an area. Further studies will reveal whether these laws also have parallels with other commodities than fluid milk.

Joyce C. Brown: the drainage pattern of the lower ottawa valley

Above its confluence with the St. Lawrence the Ottawa River expands to form the Lake of Two Mountains, which cuts across the Precambrian inlier forming Oka and Rigaud Mountains. It is suggested that the ancestral Ottawa River followed a less anomalous course between Oka Mountain and the edge of the Precambrian Shield.

Oka Mountain forms a barrier to direct drainage into the lake from the north. The North River enters the lake near its head and its tributaries drain much of the area between Oka Mountain and the Shield edge. The pattern of this river system is strongly influenced by parallel morainic ridges which rise from beneath the later Champlain Sea deposits.

The Rigaud and Raquette Rivers are the main southern tributaries. The latter follows a pre-existing valley cut in the bedrock of the eastern flank of Rigaud Mountain.

The drainage pattern has evolved during the retreat of the late-Wisconsin Champlain Sea which submerged the area to 600 feet. During the emergence of the land, which was greater to the northeast than to the southwest of the area, the Ottawa valley carried the discharge of the upper Great Lakes. Channels cut by branches of the Ottawa River at different elevations may be traced across the area and correlated with successive shorelines in the basin of the Lake of Two Mountains. Many of the present streams follow such channels, although in several instances differential uplift has reversed the direction of drainage. The most notable example of such reversal is the North River in its course along the Shield edge between St. Jerome and Lachute.

J. D. Chapman: energy supply of british columbia

During the period 1946–60 the energy requirements of British Columbia increased at 6.8 per cent per annum compared to 2.9 per cent per annum for Canada as a whole. A large proportion of this energy is consumed in the urban areas of the southwest coastal area, in Trail and Kitimat, while an increasing proportion of the supply has originated in northeastern British Columbia and Alberta. This paper deals with the production of primary energy in British Columbia and its transfer to the major consuming areas.

Aubrey Diem: land reform and reclamation in sicily

The many problems of land reform and

reclamation in Sicily stem from the geographical situation of the island, the historical evolution of agrarian practices and land utilization, over-population, lack of resources necessary to maintain modern industry, and the continued aggravation of existing conditions by the social and political climate of the region. The purpose of this paper is to discuss land reform and reclamation in Sicily by examining the physical limitations to Sicilian agriculture, briefly tracing its historical evolution, and describing and evaluating the efforts of the *Ente per la Riforma Agraria in Sicilia* (Agency for Agrarian Reform in Sicily) and the *Cassa per il Mezzogiorno* (Fund for the South) on the rural land use.

Since 1950, the Central and Regional Governments have carried out a programme of land reform and reclamation including: (1) breaking up the large estates for distribution to peasant farmers and resettling the peasants on individual farmsteads or in newly constructed rural villages, (2) introducing modern tools and techniques of cultivation, (3) controlling erosion by the construction of dikes and check dams, terracing, and reforestation, and (4) increasing the irrigated area through the construction of dams and accompanying reservoirs.

There is some question whether certain aspects of the reform programme have been formulated with much understanding of Sicilian geography. Since 1950, the amount of land redistributed to the peasants has been negligible and many of the newly constructed farmhouses and rural villages have been abandoned. In many cases, newly introduced tools and techniques of cultivation have contributed to the erosion of the already meagre soil resource rather than the increase of productivity. The necessary number of trees needed to check erosion and the silting of reservoirs has not been planted and waters from the newly formed reservoirs intended for irrigation have been misused. It is evident that the capital investment of the *Cassa per il Mezzogiorno* and the *Ente per la Riforma Agraria in Sicilia* has not appreciably raised the living standards of the impoverished peasants within the last ten years.

R. Garry: quelques reflexions sur l'evolution de la population sovietique

A l'occasion du recensement de 1959 un certain nombre de données précises ont été pour la première fois publiées en U.R.S.S. notamment : évaluation globale de la population, répartition par sexes, décomposition par république et par province, croissance des principales villes, répartition par nationalités. Grâce à ces documents il est possible de dresser les cartes de répartition de la population urbaine et rurale par république, territoire et région, de représenter graphiquement la croissance des villes de plus de 50,000 habitants entre 1939 et 1959, d'étudier la répartition de l'élement ethnique russe et slave dans l'ensemble du territorie soviétique.

L'augmentation de la population urbaine résulte non seulement de l'accroissement naturel mais encore d'un déplacement des populations rurales vers les villes nécessité par l'accroissement continu de la production industrielle. La comparaison des chiffres de population des villes entre 1939 et 1959 fait apparaître des taux d'accroissement fort divers et la naissance de villes nouvelles; elle permet de déterminer les zones de développement économique maximum. La répartition des nationalités fait ressortir l'implantation russe et slave dans les diverses régions de l'Union Soviétique consécutive l'effort d'industrialisation et au souci des dirigeants russes d'opérer un brassage progressif des populations en vue d'en hâter la russification.

Louis-Edmond Hamelin: notes sur le periglaciaire du Spitsberg

Les premières recherches périglaciaires au Spitsberg (à partir de 1910) ont contribué à orienter les études périglaciaires mondiales vers celle des « patterned ground ».

Au Spitsberg, le périglaciaire est à la fois climatique et de situation. Le cycle gélival, le fluvio-périglaciaire, le glaciel, le permafrost, la semi-aridité et les fortes oppositions saisonnières forment les principales conditions. Les terrasses littorales offrent un terrain de choix pour le développment de certains sédiments et formes.

Nous avons classifié les phénomènes vus dans les groupes suivants : (1) permafrost et mollisol; (2) « patterned ground »; (3) gélifraction et éboulis; (4) gélifluction; (5) glaciel; (6) glacitectonique; (7) divers.

L'évolution du périglaciaire spitsbergien ne s'est pas toujours faite au même rythme au cours du postglaciaire; aussi les formes portent-elles traces de diverses hésitations climatiques; les versants et les «patterned ground » notamment montrent l'effet de ces « reprises ».

W. Henoch: reconnaissance of glacial features in the western half of the Arctic Red River map area

This paper discusses the glacial features of the area represented by the western part of

the Arctic Red River map sheet (Sheets 117 SW and 117 SE, scale 1:506,880). The evidence of glacial erosional and depositional forms suggests that the continental ice sheet covered the Mackenzie Lowlands and the plateau north of the Mackenzie River, extended over the Mackenzie Delta and Peel Plateau, and abutted the eastern slopes of the Richardson Mountains. The Richardson Mountains remained free of extensive glaciation.

The Doll River and its tributary valleys in the most southerly part of the Richardson Mountains are filled with lateral moraines which were deposited by glacier tongues, probably of the Cordilleran glaciation.

The various types of meltwater channels and their locations are described, and used as indicators of the approximate thickness of the ice sheet as well as its westward extent. The glacial drainage pattern suggests the existence of subglacial and englacial channels. Although the front of the ice reached many valleys of the Richardson Mountains, no traces of ice-dammed lakes were found in them. It appears that a temperate climate prevailed and that subglacial and englacial drainage prevented formation of damned lakes.

The terraces of the Mackenzie River and their age are discussed and the evidence for more than one glaciation is considered.

D. J. M. HOOSON: A NEW SOVIET HEARTLAND?

A curiously disconcerting feature of Mackinder's original "Heartland" was that its geographical significance in world power appeared to be largely independent of its population and natural wealth. Since Mackinder wrote, part of his Heartland area has exhibited an exceptionally rapid influx of population and has turned out to be one of the world's great storehouses of industrial resources. Presumably whatever inherent geographical properties the Heartland may still possess cannot but be reinforced by such positive developments.

The zone to which attention is drawn is an elongated one, stretching from the Middle Volga to Lake Baykal. Several sub-regions can be distinguished, but in all of these the growth of cities (over 50,000) has been more rapid since 1939 than it has in any of the Soviet regions outside the Volga-Baykal zone. Over 40 per cent of the entire Soviet net increase of city population since 1939 has accrued to this zone, and in the plans for the present decade it looms disproportionately large.

This zone, which still houses only a quarter of the Soviet population, now appears to contain the lion's share of the accessible Soviet resources of all forms of power and of most of the metals and minerals needed for the industrial expansion now well under way. The agricultural base has been greatly broadened in recent years and the transport network extended. Moreover (and this is where Mackinder might still come in) no part of this Volga-Baykal zone came within the grasp of the German invaders in the late war.

F. C. INNES: LAND SETTLEMENT AND ABANDONMENT: THE QUEBEC CLAY BELT

At the turn of the century the French-Canadian milieu was suitable for the launching of a new land colonization epoch. Church and state combined and many new parishes were founded on virgin land, especially in the northwest of the province.

Since that time, the increasing opportunities in the towns and industries of the province together with a significant change in accepted social values has led to a steady decline in farm population, punctuated only by short periods of acute industrial unemployment when even marginal lands have regained some attractiveness. Thus the frontier has been the scene of retreat and reassessment in prosperous times, but has acted as a refuge for subsistence agriculture in times of economic depression.

J. D. IVES: ECONOMIC IMPLICATIONS OF IRON MINING IN PERMAFROST IN CENTRAL LABRADOR-UNGAVA

The decision to undertake large-scale mining of iron ore in the vicinity of Schefferville was partly based upon the proving of 500 million tons of ore reserves. This essential economic consideration set in motion one of the largest commercial developments of the Canadian northland. It is evident that the decision was based upon an automatic presumption that the ore was "normal," in the sense that it was not permanently frozen.

Today it is being realized that a large proportion of the initial proven reserves are permanently frozen and that the cost factor in frozen areas is double the initial expectation of 1954. This aspect of the economic geography of Labrador-Ungava is discussed and an outline is given of the technical problems involved in mining permafrost. The extent of permafrost in Labrador-Ungava is obviously a vital factor in economic exploitation. Knowledge of permafrost conditions,

however, is inadequate and vague, even in the main ore-producing areas. The paper is concluded with a preliminary outline of permafrost distribution in relation to the ore-producing and potential mining areas known today.

W. A. Douglas Jackson: THE VIRGIN AND IDLE LANDS REAPPRAISED

More than half a dozen years have lapsed since the Soviet regime undertook to increase the national grain supply by ploughing vast areas of virgin and idle lands in the eastern regions of the country. It would, therefore, seem worthwhile in view of the claims that the regime has made concerning the successful completion of the programme to re-examine and reassess the Soviet efforts in the light of the available evidence.

Under dry farming, where rainfall is unreliable, fallowing is essential. Yet there has been considerable evidence to suggest that in the past, in western Siberia and northern Kazakhstan in particular, a fairly common practice was to sow wheat year after year on the same land. If practised, fallowing and crop rotations were little more than nominal in many areas. Indeed, the very lack of fallowing gave rise to such large reserves of idle land. These lands, cultivated to the point of exhaustion, had been lying idle for many years. Yet, with their ploughing in 1954–6, old crop land should have been taken out of cultivation. However, this has not been the case to any considerable extent. Nor has summer fallowing (par) been introduced very widely. Because of enormous grain delivery quotas, crop lands have been kept in wheat and other grains. Soil deterioration is proceeding rapidly and even as early as 1956 there were reports of serious erosion, particularly in Kustanai and Pavlodar Oblasts in Kazakhstan.

Aside from the natural handicaps that have impeded the virgin lands programme, there have been other difficulties. The housing situation, now somewhat improved, has been desperate, supplies of drinking water have been inadequate, deliveries of equipment have been slow, tractors and harvesters have stood idle for want of parts and repairs, grain elevators have not been built on time, and there have been both sowing and harvesting delays. Yet the country, as a result of this enormous programme, has increased its overall production of grain. But, if the short run has triumphed over the long run, if the future has been sacrificed to the present, with the steady increase in population in the U.S.S.R. and the ever-growing demand for a better diet, the virgin land programme may turn out to be a prime example of short-sightedness.

C. Langlois: THE EFFECTS OF LAND SPECULATION ON RECENT PATTERNS OF GROWTH IN GREATER MONTREAL

Montreal, like all other larger metropolitan areas in North America, has undergone intensive suburban growth since the end of World War II. In Montreal this growth has formed four different patterns during the past fifteen years. First, from 1945 to 1951, rapid circular growth could be seen; this was an accretion pattern. From 1951 to 1956 the growth ranged further out along the main transportation lines; this was the radial-nodal pattern. The short period which followed, from 1956 to 1958, saw a radial-internodal pattern of growth. Since 1958, a new pattern has been taking place—a disorderly widespread dispersal.

These various patterns of suburban growth were brought about by a score of different factors: local physical and social characteristics of the Montreal region, the piecemeal distribution of municipalities, the availability of services, and the industrial decentralization, to name a few. Two large-scale waves of land speculation, particularly the more recent in 1957–8, are perhaps the most influential factor currently shaping the pattern of growth in Montreal.

A. Laycock: DRY FARMING AS A MEANS OF WATER CONSERVATION IN THE PRAIRIE PROVINCES: A CRITIQUE

Dry farming practices were slow to be accepted in the prairies in the early days of settlement. Government agencies promoted two- and three-year rotations including fallow and experience soon showed their value. It is probable that these rotations are now too rigidly employed and that we should use better criteria in determining when and where the land should lie fallow. Some of the alternatives to the present practices, including some based upon climatic patterns and soil measurements, are discussed.

J. G. Nelson: THE PROBLEM OF PRE-EUROPEAN TRADE BETWEEN AUSTRALIA INDONESIA AND THE ASIATIC MAINLAND

Although its beginnings are mysterious, trade between the Asian mainland and Indonesia was well developed long before the coming of the Europeans. The question is

whether this traffic extended to Australia in pre-European days. The Malays are known to have traded with the Australian natives in the eighteenth and nineteenth centuries. At that time, they sold Australian trepang to Chinese sailors in southern Indonesia for resale in Canton. According to a number of the Malay sailors involved, this trade was a development of the European period. However, a study of the physical, nautical, archaeological, and cultural evidence suggests that the trade probably began several hundred years prior to European entry into the Pacific.

J. H. Richards: Changing Canadian Frontiers

The impress of Canadian geography upon the economy and policies of this country has always been strong. Recent policies may be treated, with considerable pertinence, as outgrowths either of belated recognition of the facts of geography or/and of cognizance of the changing character of orientation, distance, and communication which has been thrust upon us. It is these recent policies, implemented or inferred, that provide the focus of this discussion.

"Changing Canadian Frontiers," is suggestive of a nation bursting at the seams, moving onward and outward from that occupied and pampered zone of southern Canada. It would be possible to discuss Canadian frontiers from this viewpoint; such an approach certainly would be comfortable and the concept could be illustrated fairly easily. Such ideas may be incidental to parts of the topic here presented but they are not inherent in the intention.

The "frontiers" examined are based upon three definitions of the term: (*a*) an advanced region of settlement; (*b*) the part of a country facing an unsettled area; (*c*) the border between states. These definitions correspond, in this discussion, with the Agricultural Frontier, the Northern Frontier, and the Canadian—United States Border. The enunciation of policies, or policy statements, relating to these frontiers has gained some clarity in the present federal government; but no matter what government were now in power the same facts of geography would have to be faced and it is likely that similar policy decisions would be made.

The intention is not to analyse the political motives for or the possible results of these policies but, rather, to point up the pertinent aspects of Canada's geography and to examine national policies in relation to these facts.

W. Summers: Recent Developments in Bogland Cultivation in Newfoundland

The success in Newfoundland of recent experimental agriculture on sphagnum peat bogs suggests that we should revise upward our estimates of the extent of cultivable land in Canada.

The introduction of improved ditching equipment along with precise liming and fertilizing techniques has resulted in the production of grains, grasses, and root crops with yields far above the average normally produced from the mineral soils. Cattle and sheep thrive on extensive grasslands within three years from the time of initial reclamation.

The costs of bogland development are less than those required for the mineral soils and subsequent farm practice can be more efficient because of the huge acreages of level land that are available. Natural or green manuring is unnecessary and there is a constant certainty of an adequate supply of water.

On the mineral soils cultivation is rarely economically feasible and is successful in but a few places favoured by superior soils or by market proximity. Local crop and livestock production has declined markedly in recent years while population has shown substantial gains. There is thus a new optimism in agricultural circles fostered by the belief that a complete renewal of the agricultural régime is now possible. Thousands of square miles of land of this nature are available in the province.

D. Watts and S. I. Smith: Evapotranspiration and Energy Relationships at Waterford, Barbados, 1959–60

The McGill University Tropical Research Station at Waterford, Barbados, now a section of the Bellairs Research Institute of McGill University in Barbados, was established in 1958, with the intention of undertaking investigations into the heat and water balances of a tropical trade-wind island area, and making a case for the development of agrometeorology in an area which is densely populated and largely dependent on agriculture. Measurements of evapotranspiration and evaporation were commenced at the station in May 1959; recordings of incoming solar radiation have been made since September 1960, but records of daily sunshine totals make it possible to compute the incoming solar radiation before this date.

This brief paper summarizes the results of

investigations undertaken to date, with a discussion of the relationships between the various methods of estimating evapotranspiration and evaporation, their variations on a seasonal basis, and their relations to the incoming solar radiation totals. The percentage of solar energy which is used in the evapotranspiration processes is also calculated, and the seasonal variations reviewed.

P. J. Williams: unfrozen water in frozen soils

It has long been known that some water in soils remains unfrozen at temperatures below 0° C. More recently, it has been realized that there is no single freezing-point for water in soil, but that it freezes progressively as the temperature is lowered. Significant quantities of water are still unfrozen at temperatures well below 0° C.

A calorimetric apparatus has been constructed to determine the amount of unfrozen water in soil samples. The apparatus permits continuous determination of unfrozen water content of a soil sample passing through a range of temperature below 0° C. It has been found, for example, that over half the water present in a moist clay is unfrozen at −6° C and over a quarter of that in a fairly dry silt at −1° C. The influence of grain size and particle surface area is indicated by the high unfrozen water content of fine-grained soils, compared with that of coarser grained soils. The amount of unfrozen water present at a given temperature is different for a frozen soil that is undergoing cooling to that for a soil undergoing warming. The amount of unfrozen water present depends, therefore, on the thermal history of the soil.

The unfrozen water content is of greatest importance in that range of temperature below 0°C commonly experienced under natural conditions. Consideration of the amount of unfrozen water and its eventual freezing or thawing is essential in studies of depth of frost penetration, of the increase or decrease of permafrost, etc. The unfrozen water is a significant factor in considerations of permeability, weathering processes, and strength of frozen ground.

B. Zaborski: the Yeniseyan slope of the Siberian Highland

The Siberian Highland is broken by a system of parallel N-S faults along the valley of the river Yenisey. These faults affect also the Yeniseyan range which is practically a part of the Highland. The irregular uplift of the Siberian Highland created conditions for the rejuvenation of its surface; the slope is dissected by numerous valleys tributary to the Yenisey, the forms of which are largely controlled by the presence or absence of the trap cover.

The northwest "corner" of the Highland, the dome-like Mt. Putorana, is the highest portion of the plateau (5,188′). In the late stages of the last glaciation it was a local centre from which glaciers descended in several directions (it resembles the Lake District in England). Trough-like valleys, partly filled with lakes, have terminal moraines at their outlets.

The highland slope and the Yenisey valley have been followed in pre-historic times, and in history, by several groups of peoples in their migratory movements. The Samoyeds moved along here to the tundra from their ancient Sayan-cradle. The Russians followed it in their early seventeenth-century explorations. The slope represents one of the clearest boundaries between geographical regions.

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